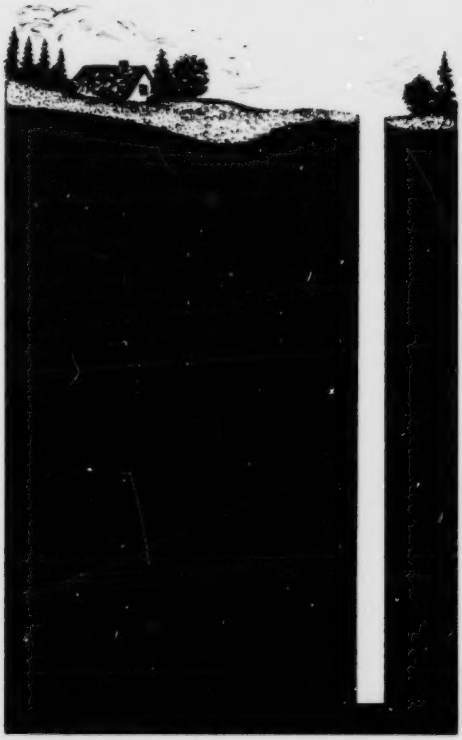
Water Wells & Ground Water Supplies In Ontario



Environment Ontario

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WATER WELLS AND GROUND WATER SUPPLIES IN ONTARIO

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Ontario Ministry of the Environment

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Additional copies of this booklet may be obtained from the:

Water Resources Branch, Ontario Ministry of the Environment, 135 St. Clair Avenue West, Toronto, Ontario M4V 1P5

Ontario Ministry of the Environment Regional and District Offices (addresses listed in Appendix D).

PREFACE

This publication is intended primarily as a guide for those planning to use ground water as a source of water supply and for those wishing information on the proper maintenance and operation of a well water supply system. Included is basic information on the preconstruction planning for a well water supply, the construction of a well, the maintenance and equipping of a well water pumping system and a discussion of common problems associated with wells. Because the quality of ground water is very important to the homeowner, there is a section on ground-water quality problems and a description of the common treatment techniques that are available. In addition, Ontario Regulation 612/84 governing the well construction industry in the Province of Ontario is discussed. It should be stressed that this publication is not intended as a do-it-yourself manual on well construction or pump installation since both of these operations require considerable training and experience.

This publication is the first revised edition of *Water Wells and Ground Water Supplies in Ontario* since its publication in 1980. Certain portions of this edition have been expanded and rewritten to reflect changes that have taken place in the regulations concerning water well construction and in the "Ontario Drinking Water Objectives." Changes have been made to illustrations and to some sections of the publication to provide more detailed coverage of the subjects.

The Water Well Industry in Ontario is regulated by the Ministry of the Environment under the Ontario Water Resources Act. The licensing of well contractors and well technicians and the construction requirements for water wells are regulated by Ontario Regulation 612/84. Regional staff of the Ministry of the Environment are responsible to see that the Act and all regulations pertaining to ground-water supplies are enforced equally across the Province.

ACKNOWLEDGEMENTS

Editing, rewriting and incorporating material in the revision of this publication originally written by G. Funk, W.A. McClenaghan and C. Holland was completed by F.P. McKenna. The comments, assistance, and critical review by many of the staff of the Water Resources Branch and others from various disciplines in the Ministry of the Environment is gratefully acknowledged, for without their participation and co-operation this publication would not have been completed.

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CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO MINISTRY OF THE ENVIRONMENT PUBLICATIONS METRIC-IMPERIAL CONVERSION TABLE

Multiply Metric (SI) Units	By	To Obtain Imperial Units
Centimetres (cm)	0.394	Inches (in)
Metres (m)	3.28	Feet (ft)
Litres/minute (L/m)	0.220	Gallons per minute (gpm)
Litres/sec (L/s)	13.2	Gallons per minute (gpm)
Litres (L)	0.220	Gallons
Kilopascals (kPa)	0.145	Pounds/sq. inch (psi)
Degrees Celsius (°C)	1.8	Degrees Fahrenheit (°F)-32
Milligrams per Litre (mg/L)	1.0	Parts per million (ppm)
Milligrams per Litre (mg/L)	0.07	Grains per gallon (gpg)

1. INTRODUCTION

GENERAL

An adequate water supply is a necessity for any residence. It must yield sufficient water at a constant and dependable rate to meet the requirements of the user and the water quality must be suitable for all household demands.

There are two principal sources for a water supply, surface water which includes natural and man-made lakes, rivers and streams, and ground water which includes wells and springs.

Ground water, which will be discussed in this publication, can provide a relatively inexpensive and constant supply of potable water. It is less susceptible to contamination than surface water and has a nearly constant yearly temperature ranging from 8 to 12°C, unlike surface water whose temperature may fluctuate seasonally over much wider ranges. Most ground water in Ontario can be used without chemical treatment.

The process of finding a ground-water source has changed considerably over the years. Ground water was once located almost exclusively by "water witching," a method which has been determined to have *no* scientific basis. Today, modern hydrogeologic methods have increased the probability of finding a good source of ground water. Finding a ground-water source involves the systematic collection and examination of available well and hydrogeologic information and based on that data making an assessment of local ground-water conditions.

The construction of water wells has also changed considerably since the time when they were dug with pick and shovel to depths of up to 30 metres and sometimes more. Today, modern drilling equipment allows wells to reach depths in excess of several hundreds of metres. Similarly, water wells and water supply systems today are more reliable than their predecessors. A properly constructed, tested, and maintained well suitably located will probably never go dry nor be contaminated by shallow polluting sources such as septic tank systems or surface drainage.

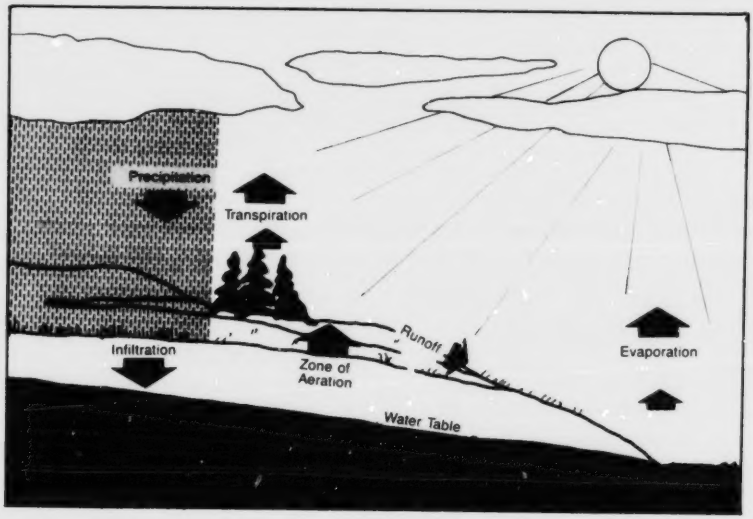


Figure 1. Hydrologic Cycle

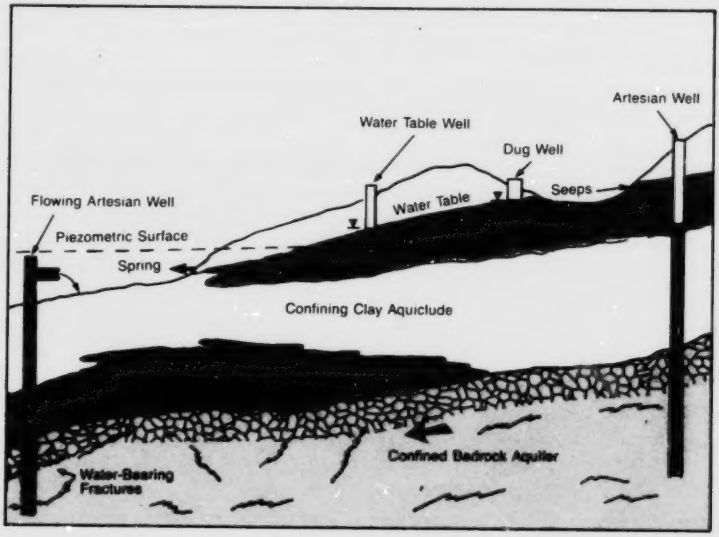


Figure 2. Water-Bearing Formations

THE HYDROLOGIC CYCLE

The "hydrologic cycle" or water cycle illustrated in Figure 1 is a complex cycle of events which involves the circulation between land, atmosphere and ocean of water as water vapor, rain, snow, ground water and surface water.

This cycle of events, although it has no real beginning and no end, can be assumed to start with the evaporation through the sun's energy of water from the oceans, lakes, rivers and soil. The resultant water vapor condenses to form small droplets of moisture which are kept airborne in clouds. Changes in atmospheric temperature or pressure create an imbalance resulting in precipitation as rain or snow. A large part of this precipitation is temporarily retained by the soil and is eventually returned to the atmosphere through evaporation and transpiration by plants. The remainder will either run off the land surface as overland flow or by interflow or ground-water flow move by subsurface flow paths to discharge to rivers, lakes or oceans.

GROUND WATER

Precipitation falling on the ground's surface will infiltrate and move downward through the soil until it reaches the *zone of saturation*. At the zone of saturation, the water fills the pore spaces between grain particles in the overburden, and fills the crevices and fractures in the rock. The upper surface of the zone of saturation is called the *water table*. The depth to the water table depends on the nature of the geological materials, the season and the slope of the ground surface. The depth may vary from less than a metre below the surface to over 50 metres. An illustration of the subsurface environment through which ground water moves is provided in Figure 2.

In the zone of saturation, any geological material or formation which is capable of yielding water to wells in usable quantities is called an *aquifer* or a *water-bearing formation*. Aquifers may be found in the bedrock and in the overburden (unconsolidated materials) overlying the bedrock. In the overburden, aquifers consist of sand and/or gravel. A coarse saturated gravel formation is a good aquifer while a fine sand or silt formation is indicative of a poorer aquifer as it will yield water more slowly. Aquifers vary in thickness and areal extent. An aquifer of limited areal extent and having poor aquifer characteristics may only be able to supply the water needs of a few households. Other aquifers have

demonstrated that they have the potential to supply the water needs of entire communities.

A formation which is saturated but does not yield water rapidly enough to furnish an adequate supply of water is called an *aquiclude*. Examples of aquicludes are clay formations or poorly-fractured rock formations with few interconnected pore spaces.

An aquifer that is overlain by confining low permeability materials (an aquiclude) and in which the water in the aquifer is under pressure in excess of atmospheric pressure is called an *artesian* or *confined aquifer*. An aquifer in which the water table or the surface of the saturated zone is at atmospheric pressure is called a *water table* or *unconfined aquifer*. The pressure in the artesian aquifer is caused in part by the weight of the confining materials, the elevation differences in the aquifer, and the restriction in movement of ground water in the aquifer. The imaginary surface formed from the water levels in wells penetrating an artesian aquifer is called the *piezometric surface*. Should the elevation of the piezometric surface in an area be higher than that of the ground surface then the wells constructed in the artesian aquifer will flow.

2. PLANNING A WATER SUPPLY

WATER REQUIREMENTS

Once you have decided that a well is the best means of providing an adequate water supply, you should determine the quantity of water required to meet your household needs. The water requirements of a modern household and farm have increased considerably over the years because of the demands of automatic washing machines, dishwashers, swimming pools and automated farm equipment. The water requirements of the modern summer cottage may not differ significantly from those of the fully equipped family home. When planning your water supply system, you should consider both your present and future water needs.

Domestic water needs are estimated to be 270 to 450 litres per day per person. A family of five for example, would require about 2,250 litres per day (at the higher rate). This amount is called the total daily demand. It is also important to take into account the demand during peak periods of use. The peak domestic demand usually occurs once in the morning and once in the evening and is approximately one hour in duration. The peak demand in the example above is obtained by dividing the total daily demand by 120 (2 hours). The peak domestic demand would therefore be 19 litres per minute (L/m), and the well would have to be able to produce 19 L/m or the system would have to include a water storage tank(s) which would have sufficient capacity to make up for any deficiency in well production. On most dairy farms, two-thirds of the total daily water requirement is used during the periods of peak demand (1 hour); therefore, the total daily farm water requirement is divided by 3 rather than 2 hours to obtain the pump capacity.

Farm water needs may be calculated by using the following table.

TABLE 1 FARM WATER REQUIREMENTS (LITRES PER DAY)

Each member of the family (Kitchen, laundry, bath)	270 to 450
Each producing milk cow (including washing)	132
dry cow	45
steer	45
horse	45
hog	15
sheep	8
chickens (100)	19 to 38
turkeys (100)	38 to 68

Farm irrigation requirements will not be discussed here and for information on irrigation you should contact your Regional Office of the Ontario Ministry of Agriculture and Food.

Additional information on water requirements is provided in Section 4 under "Well Pumps" (see pages 37-38).

PERMIT TO TAKE WATER PROGRAM

The Ontario Ministry of the Environment administers the Permit to Take Water Program under Section 20 of the Ontario Water Resources Act. A permit is required for the taking of more than 50,000 litres of water a day from any source including a well. A permit is not required for the taking of water for domestic and general farm purposes. More detailed information and application forms for a Permit to Take Water are available from the Ministry of the Environment Regional Offices.

The main purpose of the permit legislation is to control the taking of water to promote its efficient development and beneficial use. The permit system is utilized to prevent water supply interference problems where possible, and to resolve interference complaints.

In an area where there is insufficient ground water to meet established and new uses, an evaluation of the relative priority of the various uses is necessary. The taking of water for private domestic and farm purposes is considered the most important use, generally followed by takings for municipal water supply. The taking of water for industrial, commercial and irrigation purposes is regulated by the availability of the supply, the efficiency of the use and the established uses in an area. With respect to water well takings, the program is designed to provide protection to prior uses of ground water, a protection generally lacking under common law. Priority of time and the adequacy of an affected water supply prior to interference are basic considerations in assessing ground-water interference problems.

Taken together, these two factors mean that if a new water well taking, under permit, interferes with another water supply obtained from an adequate well source which was in use prior to the date of issuance of the permit, the permittee is required to restore the affected supply or reduce the permitted taking so as to eliminate the interference. Well owners and operators who feel that their supply is being interfered with by a local water withdrawal should report the details to the appropriate

Regional Office of the Ministry of the Environment. Conversely, when an individual is planning to construct a well supply that will have a large rate of withdrawl, consideration should be given to its possible impact on existing local water uses.

GROUND-WATER AVAILABILITY AND SUPPLY

Before constructing a well you should obtain as much information as possible on the ground-water (hydrogeology) resources of the local area. In many areas of the province ground-water conditions have been examined and information can be obtained from the appropriate Ministry of the Environment Regional Office, local well contractors, local agricultural representatives and neighbours.

An important source for information on ground-water conditions in your area are the Water Well Records on file with the Ministry of the Environment. Ontario Regulation 612/84 requires that all well contractors submit upon completion of a well a copy of the Water Well Record to the owner of the new well and to the Ministry of the Environment. The record provides information on the well's location, owner's name, date of construction, geological log, water quality record, well construction details, test results, well yield, water use and the recommended pump setting. Also included is the name and address of the licensed well contractor who drilled the well. A copy of the Water Well Record form is included as Appendix B to this publication.

Examination of the Water Well Records of wells installed on adjacent properties will provide you with information helpful in assessing your local ground-water and well water conditions. The following information will be useful to you:

1. type of wells constructed in your area i.e., bored, dug or drilled
2. depth of the wells
3. types and thicknesses of bedrock and overburden materials encountered
4. quantity of water developed
5. quality of well water i.e., sulphurous, salty, fresh, or mineralized
6. recommended pump settings

Individual well records from your area may be inspected and copies obtained at the appropriate Ministry of the Environment Regional Office.

Additional information on ground-water conditions can be obtained from Ontario Ministry of the Environment Water Resources Reports, Water Resources Bulletins, and Ground-Water Probability and Major Aquifer maps. A list of the publications and maps released and the areas they assess is provided in Appendix A. Although many of the reports and maps are out-of-print, microfiche copies of the reports and bulletins can be obtained by mail or telephone from the Publications Services Section, Ministry of Government Services, 5th Floor, 880 Bay Street, Toronto, Ontario, M7A 1N8. Both maps and reports can be viewed at the appropriate Ministry of the Environment Regional Office and at both Ministry of the Environment Libraries in Toronto.

Water Resources Report Series

The Water Resources Report Series provides detailed information on the water resources of various drainage basins in the province. These reports are designed primarily to assist hydrogeologists, well contractors, municipal planners, consultants and public utilities' personnel who require information on geology, overburden thicknesses, ground-water potential, theoretical water yields, hydrologic budgets, hydrochemistry, and streamflow data.

Water Resources Bulletins (Ground-Water Series)

This series of publications on individual counties and regional municipalities in Ontario presents the water well data of all the Water Well Records received by the Ministry of the Environment. This data is also available from more up-to-date computerized printouts at a nominal cost.

Ground-Water Probability Map Series

The maps of this series are designed primarily to provide general information on ground-water and well water conditions within a county. Ground-water probability maps illustrate the availability of ground water in terms of the probable quantity of water available to wells, the depth at which water is commonly found, and the quality of water at selected sample locations. General information on the hydrogeology of the county is also provided.

Major Aquifers in Ontario Map Series

The Major Aquifers Map Series was designed to define aquifers of major areal extent and of significant water production potential within southern Ontario. These maps were intended to assist those individuals wishing to establish a ground-water supply. The maps provide data on the depth at which water has been found, as well as information on the geology, the anticipated well yields of the aquifers and the areal extent of the aquifers.

CHOOSING A SITE FOR A WELL

Care should be taken in choosing a site for a well since well construction is expensive and many well failures have indirectly been caused by poor site location. For example, a well may become contaminated because it is located too close to a source of pollution.

As a general rule, a well should be located upgradient and as far as possible from potential sources of pollution such as, septic tank systems, pit privies, barnyards, roads and highways. In addition, surface-water bodies such as, ponds, lakes, streams and reservoirs may be contaminated and under certain circumstances become a source of pollution for a well supply. Large withdrawals from a well may induce ground water from a contaminated source to move towards a well. The required minimum separation (Ontario Regulation 612/84) between a new well and a potential source of pollution is:

a) new dug or bored well without watertight casing to a depth of 6 metres below ground surface ..... 30 metres

b) new drilled well with a watertight casing to a depth of 6 metres ..... 15 metres

The spacing between wells and other water supplies and various classes of sewage systems is provided in Ontario Regulation 374/81.

Whenever possible a well should be located on ground higher in elevation than the surrounding area. Where this is not possible you should mound soil around the well and grade it away from the well. In the case of a dug well, grade beyond the area of the excavation (see Figure 4). This will prevent poor quality surface water from ponding near the well and entering the well either through interflow or directly by means of the

annulus between the well casing and the borehole, should it be poorly sealed.

The location of existing and planned surface and underground structures and utilities on the property should be established before a well contractor is hired and drilling begins for reasons of safety, cost, and ease of maintenance.

A well should not be located in an area where it will be extremely difficult to maintain such as, in a basement, below a paved driveway, under power lines, or under the eaves of a building. For example, during the pulling of a pump from a well located too close to hydro lines, the pump's riser pipe could come into contact with the hydro lines and electrocute the person holding the pipe. The Occupational Health and Safety Act, Ontario Regulation 691, s.105(1) does not allow any object within 3 metres of high voltage hydro lines (750 to 150,000 volts).

The Ontario Ministry of Transportation and Communications (MTC) requires that a property owner obtain a Building and Land Use permit prior to having a well constructed within specified distances from the boundary (the property limits) of any King's Highway and from the centre of highway intersections. Applications for permits are available from any MTC District Office or Patrol Yard.

Property owners often have their wells installed before work begins on their new home. This is an excellent idea because should a satisfactory well water supply not be found, even with a second well, alternative water supply sources can be evaluated and the building plans and estimates can be changed.

HIRING A WELL CONTRACTOR

All persons constructing wells are required by the Ontario Water Resources Act, (Section 22) to be in possession of a valid well contractor licence. The "business of well construction" is to be carried out by a well technician who must also be in possession of a valid well technician licence issued by the Ministry of the Environment. After April, 1989, all plumbers and pump installers who install or supervise the installation of pumps and related equipment in or connected to a well will be licensed by the Ministry of the Environment. Further information on Ontario Regulation 612/84 governing the licensing of the water well industry and well construction in Ontario is available from the Regional Offices of the Ministry of the Environment.

It is recommended that you enter into a written contract with the well contractor before the construction of your well begins.

You should ask to see the well contractor's licence and well technician's licence and you should read the contract thoroughly before signing. It is not usual for a well contractor to guarantee in the contract that the well will provide an adequate supply of water for your needs nor to guarantee the quality of the well water. Before signing a contract, the property owner should discuss the following items with the well contractor to help clarify what costs may be involved in the work. You may also wish to include some or all of these items in the contract. Many of these items will be explained for you later in the text.

1. The unit price per metre for drilling in rock and/or overburden or boring, digging, etc., in the overburden, whether the unit price will apply to the total depth of the well, and whether it includes the cost of the well casing

2. The unit price per metre for well casing if not included in 1

3. The inside diameter of the well casing, the casing wall thickness and the type of casing (steel, concrete tile, etc.)

4. The costs of associated items which may be installed such as, well screen, drive shoe, well seal and air vent pipe

5. The cost of abandoning the well should it be necessary

6. The estimated depth, if possible, of the completed well and the length of cased well

7. The depth at which drilling or boring will be stopped and the owner's authorization obtained to continue should insufficient water be encountered

8. The type of well to be constructed i.e., rock or overburden and whether a well screen will be installed if the well is completed in the overburden

9. The construction procedure and the action that will be taken in the event that the well encounters flowing artesian conditions, excessive gas conditions and/or mineralized water — the responsibilities of the parties to the contract in the event these special

conditions occur should be discussed and defined in the contract (see Pages 51-52)

10. The type of materials that will be used to seal (formation seal) the annular space surrounding the well casing and the depth of the seal

11. The anticipated cost of well development if itemized as a separate item

12. The cost to chlorinate the well

13. The date when construction of the well will begin

14. Will the contractor guarantee that the well will not contain sand or be cloudy after it is completed

15. Will the contractor work on the well continuously and complete it as quickly as circumstances allow and will a completion date be included in the contract

16. Will the contractor agree to return and repair the well if necessary (say within two weeks) after receiving a written complaint

17. Does the contractor install well pumps and could he provide an estimate of the cost of a pump and all associated installation charges

18. The cost to seal off water-bearing zones in the rock which yield chemically unsuitable water or unacceptably large quantities of naturally-occurring gases

When drawing up a contract, you may wish to consider some example items included in Appendix C.

FINAL WELL INSPECTION

Wherever possible the well should be inspected by the owner before the contractor removes his equipment from the site. The regulations require that on the day the well is completed, the well technician is to provide the owner with a one litre sample of well water for visual examination and he is to measure the depth of the well in the owner's presence. You should make arrangements to be on site that day so as not to delay the well contractor's demobilization from the site.

You are also advised to make certain that the well has been capped, that the water in the well has been chlorinated (Appendix E), and that you will be receiving your copy of the Water Well Record. All of these items are required by regulation.

The Water Well Record is an important document on the construction of your well and provides the pump installer with the information he needs to properly equip the well with a pump. The record should be retained for future reference in the event of problems with the well or the pump. The well contractor is required to provide you with a copy of the record within two weeks of completion of the well.

3. WATER WELLS AND THEIR CONSTRUCTION

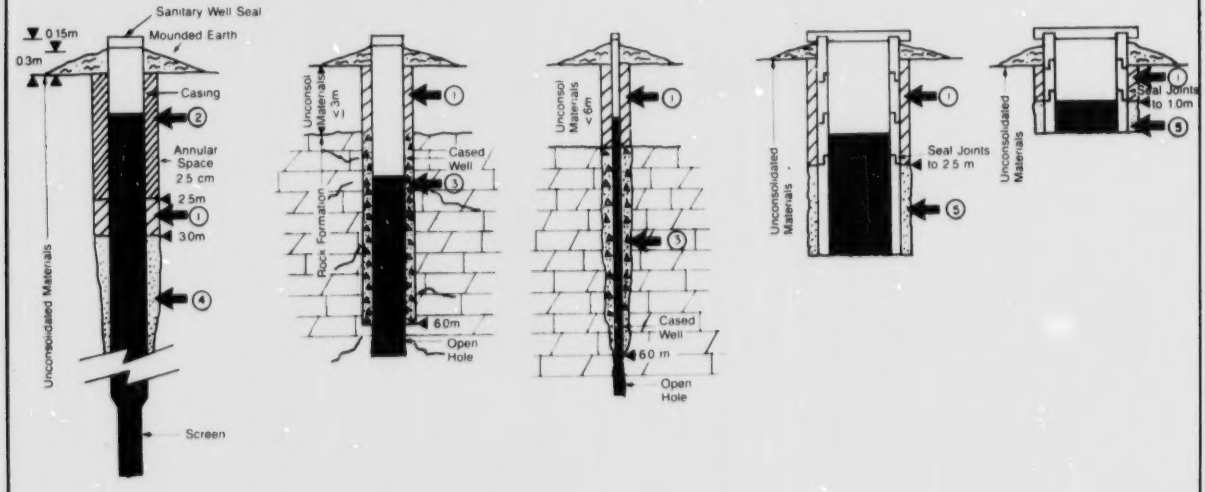
WELL TYPES

A well may be dug, bored or drilled but regardless of the construction method there are certain minimum requirements, procedures, and regulatory functions that have to followed by the well contractor in the construction of a well. The method used to construct a well is largely dependent upon the equipment and expertise of the well contractor, and the hydrogeology of the area. For example, the depth at which the aquifer or water-bearing formation is found will limit the type of equipment that can be used (see Page 17).

The well contractor is required to comply with certain minimum construction requirements established by the Ministry of the Environment and described in Ontario Regulation 612/84 and shown in part in Figures 3a, 3b and 4. These figures provide examples of the construction of several different types of wells in various hydrogeologic environments, and the material lists and depth settings for the annular seal (Formation Seal) between well casing and borehole.

To assist the individual who wishes to have a well constructed, the various well types and their application to different hydrogeologic environments are summarized in Table 2. In addition, a more complete description of the well types and the various construction methods is provided below.

To assist you in maintaining your well, the Ministry of the Environment has produced two Facts sheets entitled: "Protection of Water Quality in Drilled Wells" and "Protection of Water Quality in Bored and Dug Wells" which are available at any Ministry of the Environment Regional or District Office.



TYPE 1
Drilled well including those completed by diamond drilling in unconsolidated materials

TYPE 2
Drilled well other than by diamond drilling method completed in rock with ≤ 3m unconsolidated materials

TYPE 3
Diamond drilled wells completed in rock with < 6m unconsolidated materials

TYPE 4
Bored or dug well > 2.5 M

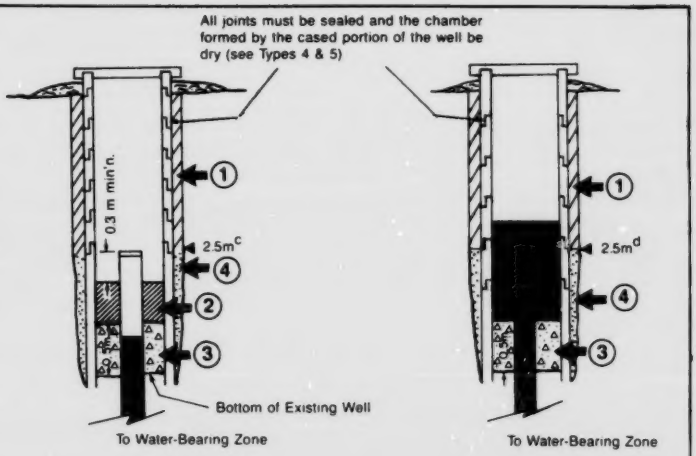
TYPE 5
Bored or dug well < 2.5 M

NOTE a) The cased portion of a drilled well shall be 6 metres deep unless a shallower aquifer is available in which case the minimum casing depth will be 3 metres

b) Formation Seal
(1) cement grout, concrete, bentonite or equivalent commercial slurry or clay slurry
(2) bentonite or equivalent commercial slurry, clay slurry, well cuttings or overburden materials
(3) cement grout or concrete

Formation Stabilizer
(4) clean washed sand or gravel, clean overburden materials or cuttings
(5) clean washed sand or gravel

Figure 3a.
Minimum Construction Requirements for Drilled, Bored or Dug Well Types



TYPE 6 (e)
Well drilled through bottom of existing bored or dug well and that well is not in service.

TYPE 7 (e)
Well drilled through bottom of existing bored or dug well and that well is to be left in service.

NOTE:

c) 2.5m or closer to land surface if necessary to prevent accumulation of water in the pit.
d) 2.5m or closer to land surface to prevent water from the bored or dug portion getting into the casing.
e) Bored or dug well must meet requirements of Types 4 and 5 before drilling through the bottom of the well should be considered.

N.T.S.

Figure 3b.
Minimum Construction Requirements for Drilled, Bored or Dug Well Types

TABLE 2: DIFFERENT WELL TYPES, THEIR APPLICATIONS, AND THEIR ADVANTAGES AND DISADVANTAGES

WELL TYPE	SUITABLE GEOLOGIC MATERIALS	ADVANTAGES	DISADVANTAGES
DUG WELLS	OVERBURDEN both low and high yielding materials (gravel, sand, silt, clay)	1) Do not require special equipment to construct 2) Large diameter provides storage reservoir to augment low yields 3) Can be constructed in areas of limited access	1) Labour intensive 2) Well depth is limited by caving conditions and bedrock 3) Water shortages are more common during dry periods because of shallow well depths
BORED WELLS	OVERBURDEN both low and high yielding materials (gravel, sand, silt, clay)	1) Efficient method for constructing large diameter wells 2) Large diameter provides storage reservoir to augment low yields	1) Well depth is limited by caving conditions, boulders and bedrock 2) Practical total working depth 30 metres
DRILLED WELLS	OVERBURDEN AND BEDROCK moderate to high yielding materials (sand, gravel, sandstone, limestone)	1) Can reach greater depths than other techniques 2) Can penetrate rock 3) Are generally less subject to contamination than other well types	1) Small diameter well casing provides little storage capacity
DRIVEN OR JETTED WELLS (Sand Points)	OVERBURDEN moderate to high yielding materials (sand and gravel)	1) Simple installation; can be done by hand or small drilling machines 2) Wells can be connected together to increase the yield	1) Small diameter well casing provides no storage capacity 2) Depth is limited by coarseness of materials in overburden and by bedrock

DUG WELLS

Hand digging a well in the overburden was the method of construction used before the development of motor-driven boring or drilling machines.

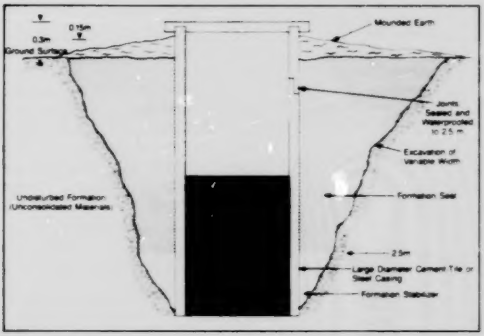


Figure 4. Dug Well

Today, dug wells as shown in Figure 4 are restricted to areas where a dependable supply of ground water exists at shallow depths and to materials which can be excavated by a backhoe. Dug wells are seldom more than 9.0 metres deep and may be 61.0 centimetres or more in diameter. Because dug wells usually do not penetrate very far beyond the top of the water-bearing formation, many dug wells experience water shortages in the summer months when the water table declines. As a result, many older dug wells have been replaced by deeper more reliable drilled or bored wells.

It is recommended that older dug wells still in use today should have their well water tested bacterially (arranged through Medical Officer of Health) and the well's structure examined and reconstructed to meet present well standards.

Dug wells are usually cribbed with concrete, brick or vitrified tile. Since they may be susceptible to pollution from surface and near surface sources of contamination, the tile joints in the upper 2.5 metres must be watertight, and the top of the upper tile must be raised above ground surface at least 30 centimetres and sealed with a well cap. The land surface around the well beyond the edge of the excavated area should be raised and graded away from the well. See "Bored Wells" for description of annular seal.

BORED WELLS

Bored wells are constructed only in the overburden and are found mostly in areas where ground water is close to the land surface. Their construction is limited to formations or materials which are stable and will not cave during excavation.

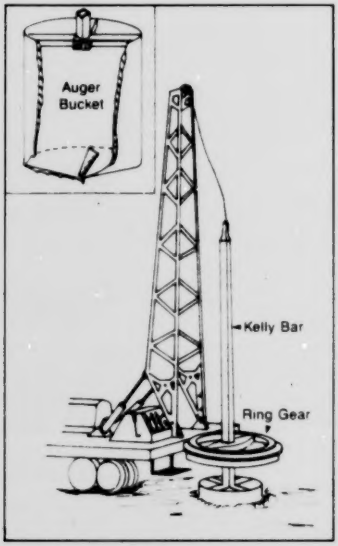


Figure 5. Boring Rig

The average depth of a bored well is under 15 metres and very few extend to depths greater than 30 metres. Common casing diameters of bored wells are 635, 762 and 914 millimetres. The large diameters of these wells provide a storage reservoir for use during periods of heavy demand. During periods of low or no demand, the reservoir is replenished by ground-water recharge.

The static water levels in bored wells are sometimes rapidly influenced by recharge from precipitation events and generally show significant seasonal patterns of fluctuation which may exceed one metre. Water shortages may occur in some shallow bored wells during the long dry periods of the summer when the static water level declines.

Bored wells are usually constructed with a boring rig (Figure 5) which rotates a cylindrical bucket equipped with cutting blades. The bucket looks similar to the bucket auger used for digging fence post holes. It is attached to a rotating kelly bar and when it is filled, it is lifted from the hole and the cuttings dumped. Boulders often are a problem in boring and sometimes it is necessary to remove them manually from the borehole.

When a sufficient supply of ground water is encountered, the well casing, usually cement tile or corrugated galvanized pipe is lowered into the borehole. Screens are seldom used in bored wells. Most well contractors will however put a few feet of washed gravel in the bottom of

both the well and the annular space outside the lower cased portion of the well to stabilize the formation and prevent the movement of sand into the well.

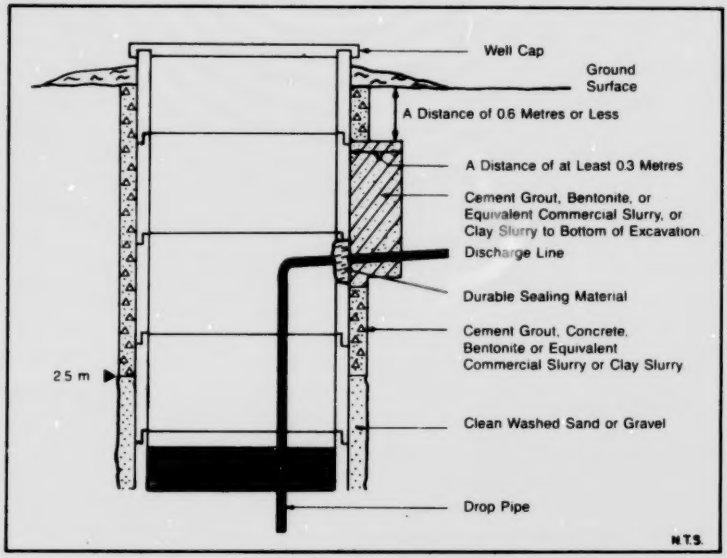

Well Cap
Ground Surface
A Distance of 0.6 Metres or Less
A Distance of at Least 0.3 Metres
Cement Grout, Bentonite, or Equivalent Commercial Slurry, or Clay Slurry to Bottom of Excavation
Discharge Line
Durable Sealing Material
Cement Grout, Concrete, Bentonite or Equivalent Commercial Slurry or Clay Slurry
2.5 m
Clean Washed Sand or Gravel
Drop Pipe
N.T.S.

Figure 6. Bored Well Pump Intake Connection

The well contractor is required to fill the annular space between the outside of the casing and the wall of the borehole, from land surface to a minimum depth of 2.5 metres, with a formation seal (Figure 3a). Below this depth the annular space is usually filled with a formation stabilizer of washed sand or gravel. All tile joints to a minimum depth of 2.5 metres below ground surface are required to be watertight.

The top of the well casing must extend at least 30 centimetres above the land surface and be sealed with a watertight cap to prevent the entry of foreign materials into the well.

The water supply connection through the casing of the bored well must be watertight and should be completed as shown in Figure 6.

DRILLED WELLS

In Ontario, wells have been drilled to depths of over 185 metres, but are more commonly 15 to 60 metres deep. Because of the type of construction and general depth, drilled wells are less likely to become contaminated and affected by seasonal water level fluctuations than shallow bored wells.

The casing of a drilled well is usually steel and has welded or threaded joints which prevent loose overburden materials and contaminated surface waters or shallow ground waters from entering the well. If a well is drilled into bedrock, the casing will usually be placed or driven up to a metre into the rock. The casing will be firmly seated in the rock with the driller usually driving the casing until he feels he has an adequate seal. This seal is necessary to prevent the movement into the well of fine sands and silts often found at the overburden–bedrock contact. In some cases, the driller may cement the well casing into the top of the rock. Drilling of the rock should proceed only after the casing has been properly seated.

The well casings must be made of new material and meet the minimum wall specification thicknesses established by the Ministry of the Environment. Although the most frequently used material in drilled wells is steel, other materials such as, plastic (ABS or PVC), brass, copper, stainless steel, and fibreglass may also be used in special cases, for example, where the corrosiveness of the well water may reduce the effective life of steel casing.

The well casing diameter must be compatible with the diameter of the proposed pumping equipment.

Some of the drilling methods used to complete wells are described below.

Cable-Tool Drilling

In cable-tool drilling, the hole is formed by the hammering and cutting action of a heavy drill stem and bit repeatedly raised and dropped. This cutting action breaks the formation into fragments which when mixed with water can be removed at intervals from the hole by a bailer or sand pump. The well casing is usually driven ahead as the hole is advanced.

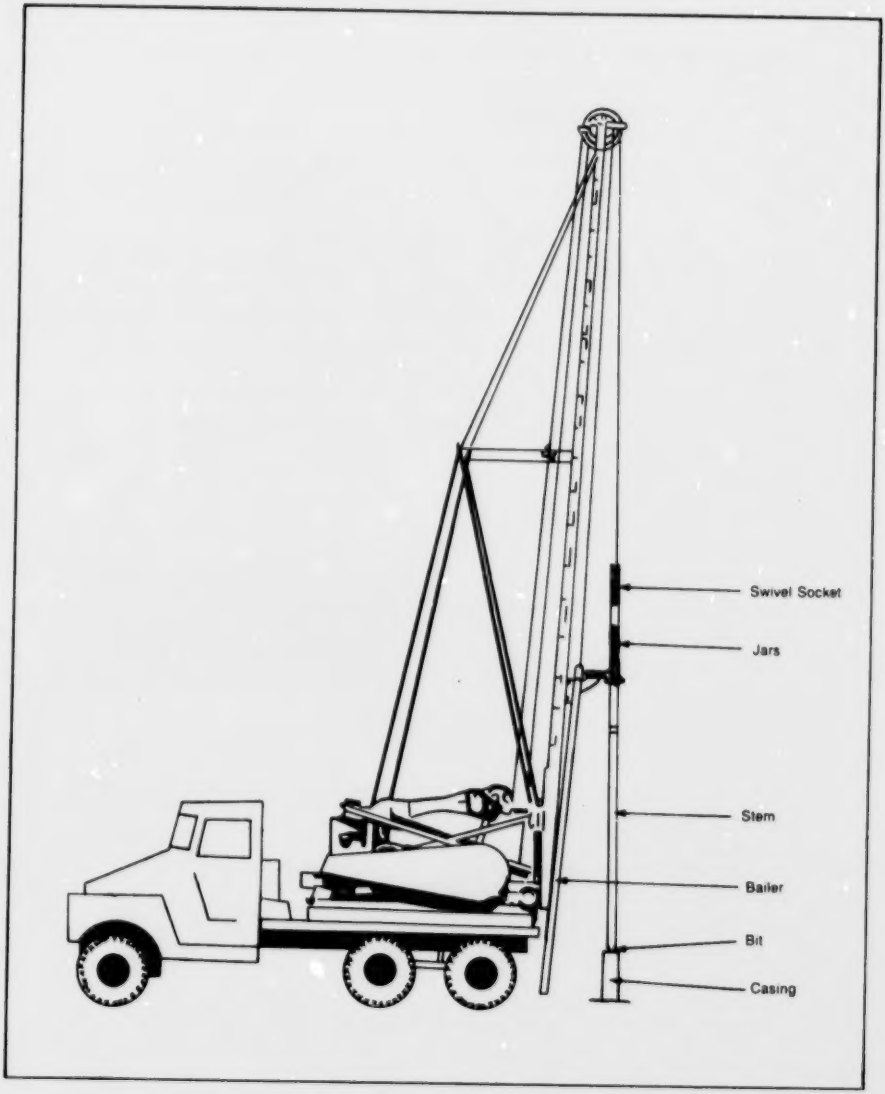


Figure 7a. Cable-Tool Rig

Figure 7(a) illustrates a cable-tool drilling rig. Cable-tool drilling is quite slow and is usually not used if a deep well is required.

Conventional Rotary Drilling

In rotary well drilling, a rotating hollow drill stem and bit cuts through the formation. The drill cuttings are removed from the hole and the hole kept open by circulating a fluid called drilling mud which is a mixture of bentonite (a commercial drilling clay) and water. The mud is pumped down the drill rods, through the bit and moves upward between the drill rods and the open hole to a surface settling pit. Well casing is not usually placed in the hole, except for a few feet of starter casing, until a suitable formation in the overburden is encountered or the hole reaches the surface of the rock. Figure 7(b) illustrates this drilling method. This method of drilling is the most common method of drilling and is much faster than cable-tool drilling.

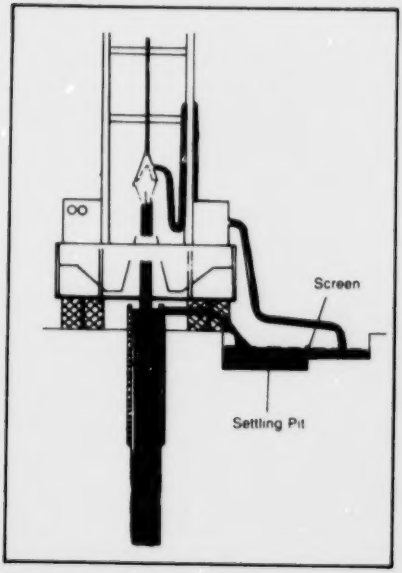


Figure 7b. Conventional Rotary Drilling System

Reverse Circulation Rotary Drilling

This method is similar to conventional rotary drilling, except that the flow of the drilling fluid is reversed. The fluid moves by gravity from a surface settling pit down the annulus between the drill rods and borehole wall, and is pumped up through the inside of the drill rods back to the settling pit. This method is used in special hydrogeologic settings primarily for the construction of large diameter (457 to 1,524 millimetre) high capacity municipal or industrial wells.

Air Rotary Drilling

This method of drilling is also similar to conventional rotary drilling, except compressed air is used instead of drilling mud in removing the cuttings from the hole. Air rotary drilling is used in the drilling of bedrock and competent overburden formations that will not collapse such as, hard clay. Figure 7(c) illustrates a cone type rotary drill bit used in air and conventional rotary drilling.

Figure 7c. Rotary Drilling Bits

Air Hammer Drilling

This method of air drilling uses a tool or bit similar to a pneumatic hammer and is commonly referred to as a "down-the-hole-hammer." The method combines the percussion effect of cable-tool drilling with the rotary action of rotary drilling. It is the fastest method of drilling hard rock formations.

Diamond Drilling

The diamond drill is used mainly in hard rock. The drill bit has diamonds set in the cutting surface. The cuttings are removed by a jet of water which also cools the bit. Most wells drilled by this method have a small diameter (50 millimetres or less) and therefore have limited application in the domestic well market.

Jet Drilling

This method consists of washing a small diameter pipe or well point, commonly 50 millimetres in diameter, into the overburden by means of a high-speed jet of water. Jetting may be done by using drill bits to aid in the cutting, by washing down a casing that is to remain after the well is completed, or by jetting in self-jetting well points.

WELL POINTS

A well point is a well screen with a tip that acts as a drilling bit threaded to a riser pipe. When in place the riser pipe can be connected directly to the pump. Well points usually vary from 25 to 50 millimetres in diameter and from one to 2.5 metres in length.

Satisfactory operation of a well point system depends upon the water table being within a metre of ground surface and the formation being highly permeable and extending from ground surface to a depth of at least 4.5 metres. If the formation is not compacted and relatively free of stones, a well point or sand point may be driven by hand.

SPRINGS AND SEEPS

Springs and seeps occur where the water table intersects the land surface or where a confined aquifer discharges to the surface. A spring is a distinct flow of water while a seep is less substantial and is indicated by wet or marshy areas. Springs are common in areas of significant topographic relief such as, the Niagara Escarpment and the Oak Ridges Moraine. Seeps are common in areas of low relief.

Springs and seeps capable of yielding sufficent water to meet domestic requirements are present in some areas of the province. Considerable discretion should be used in developing springs for water supplies because they are more easily contaminated than wells and their yields

are significantly influenced by seasonal weather patterns. It is not uncommon for springs to "dry up" in the summer months, or at least for the flow of water to be significantly reduced.

Bacterial contamination of springs is common and may occur when infiltrating precipitation moves only a short distance through the subsurface before discharging. This distance may not be sufficient to remove or filter out bacteria and other organisms which are harmful to health.

Water samples for both chemical and bacterial analyses should be collected on a regular basis from all springs and seeps which are used as water supplies. The samples should be analysed for the same parameters as new water wells. Continuous chlorination is highly recommended for spring supplies and care should be taken to protect the sanitary quality of the supply by diverting surface water away from the supply, keeping animals away from the area, and housing the spring in a protective structure with a tight-fitting cover.

Developing springs and installing equipment for spring collection is deemed to be the construction of a well and must be done in compliance with existing well construction regulations.

WELL SCREENS

Once the drilling of a well reaches a suitable sand or gravel aquifer, the well contractor upon examination of the cuttings will select a well screen. The well screen (Figure 8) is the intake portion of the well. Generally the screen will be a commercially manufactured pipe, usually of stainless steel, with small openings that permit the easy entry of water into the well while keeping out fine-grained materials.

The well screen is placed opposite the aquifer. Incorrect selection or placement of a well screen can lead to sand or silt materials moving into the well. Fine-grained materials passing through the well screen will plug plumbing fixtures, cause excessive wear of the pump and may result in the failure of a well. If a well is drilled into a coarse sand or gravel formation, it is possible that a screen may not be needed; nevertheless, it is always a good practice regardless of the coarseness of the formation to install a well screen in a drilled well. Without a well screen, the development of the well and the redevelopment of the well at a later time will not be possible. Should the well be overpumped at any time, it may never again yield sand-free water because of a breakdown in the

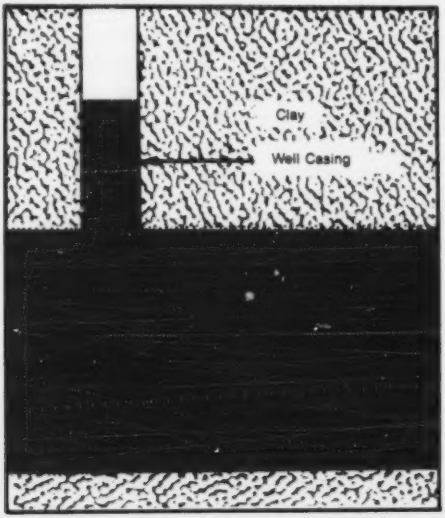


Figure 8. Well Screen

well's development. A screen with the proper sized openings will allow water to flow into the well with a minimum of resistance, thus increasing the well's efficiency and yield. Wells terminating in bedrock seldom need screens because the cracks and fissures from which water is obtained contain few fine particles.

The size of the screen openings depends on the particle size of the sand and/or gravel of the aquifer. Most screen manufacturers in the case of the larger wells will sieve samples of the aquifer material for the driller and will recommend an appropriate aperture opening or slot size for the screen. The slot size selected will allow about 60 per cent (naturally-developed well) of the formation opposite the well screen to pass through the screen during well development. The remaining 40 per cent comprising the coarser sand or gravel fraction will form a natural filter surrounding the screen. The slot size of a screen represents the width of the opening and in the metric system is expressed in millimetres, .02 mm to 3.0 mm and in the Imperial system, in thousands of an inch. For example, a No. 6 slot screen has an opening of 0.006 inches.

Two types of well screens have been used in domestic wells, the torch cut or milled slotted-pipe screen and the continuous-slot wire-wrap screen. The slotted-pipe well screen is usually a steel casing perforated by parallel, vertical slots made by a saw or cutting torch or by being milled during casing manufacture. The disadvantages of this type of screen are that it is only suitable for coarse sand and gravel formations, the area of screen opening per metre of casing is very small, and the flow of water through the screen and into the well cannot be maximized through well development. Slotted well casings are also usually not made of corrosion-resistant materials and will tend to corrode faster than continuous wire-wrap stainless steel screens. Slotted well screen is usually not recommended for permanent water supplies.

The continuous-slot wire-wrap screen is commercially made by winding a flattened wire in a spiral around a circular framework of rods. The design offers the highest open area of any well screen and provides a large number of different size aperture openings suitable for coarse to fine aquifer materials. The screen is usually made of a corrosion-resistant material such as, stainless steel as well as brass and bronze, which are also corrosion-resistant. Plastic and fibreglass screens have become available recently. They are less expensive than stainless steel and are corrosion-resistant, but they do not have the same strength or resistance to abrasion.

Installation of Screens

A common method of installing a well screen is the "pull-back method." A well casing is placed at the bottom of the hole and a well screen is lowered inside the casing to the bottom of the well. The casing is pulled back a distance equivalent to the length of the screen exposing the screen to the natural formation. The top of the screen is fitted with a flexible neoprene rubber packer or lead packer which is expanded to make a sand-tight seal between the top of the screen and the well casing.

Well screens are also installed by lowering a string of well casing with the screen already attached into the hole. In both methods the hole still contains some drilling fluids that keep the hole open and prevent the formation from collapsing. These fluids are removed during well development.

Developing the Well

Well development (Figure 9) follows the installation of the well screen. A well is developed for 2 reasons, firstly to stabilize the formation around the well screen and secondly to increase the efficiency of the well.

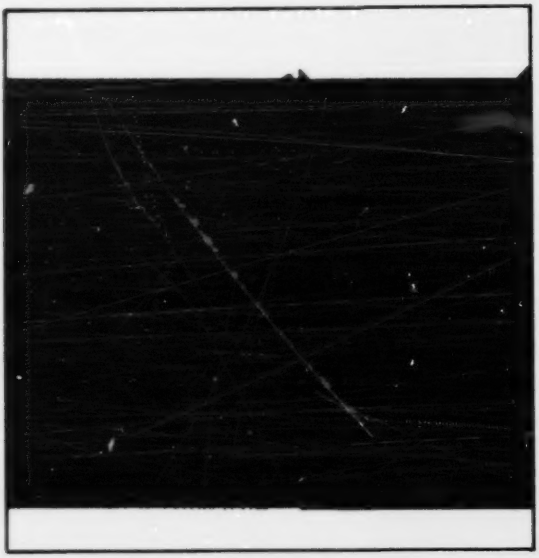


Figure 9. Well Screen Development

Jetting, surging, backwashing, and overpumping are some of the methods commonly used in the development of wells. Water or air is surged back and forth through the well screen dislodging the fine particles around it. These particles along with any drilling mud remaining in the formation and in the borehole are then pumped or bailed from the well. Development usually continues until fine particles no longer appear in the well water and the water is clear and colourless, suggesting that the formation around the screen has stabilized and the coarser sand fraction left behind has formed a natural filter or envelope of coarse sand or gravel around the screen. If a well contractor cannot develop a well to a sand-free state, he is required to advise the well owner of this condition, and to make a note of it on the Water Well Record, Ontario Regulation 612/84, s.11.

The methods used to develop wells in sand and gravel formations are also used on wells constructed in rock formations. The objective is to remove any rock cuttings, fine sand or silt that may have moved into the rock fractures and fissures in the hole during drilling. Materials left in the fractures could significantly reduce the well yield.

FORMATION SEAL

To prevent surface water and shallow ground waters which may be contaminated from seeping into a well, the well contractor is required to seal the annulus between the outside of the well casing and the wall of the borehole with low permeability materials. The sealants may be cement grout, concrete, bentonite, equivalent commercial slurry or clay slurry, well cuttings or overburden materials. The method of placement and the acceptable type of material for the various well types are described in Ontario Regulation 612/84 and shown in Figures 3a, 3b and 4. To facilitate the placement of these materials, the upper portion of the well is required to be at least 50 millimetres larger in diameter than the well casing. The annular space beneath the formation seal should be filled with a formation stabilizer consisting of clean, washed sand and gravel.

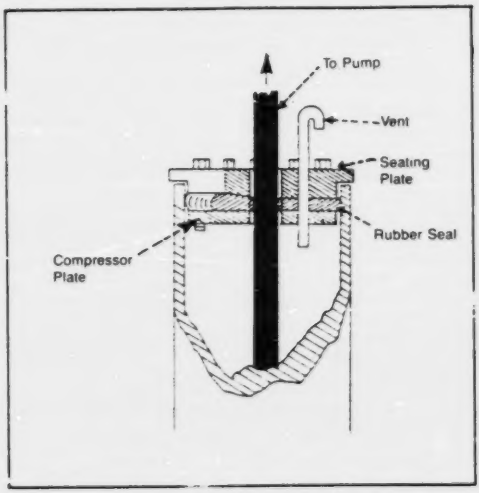


Figure 10. Sanitary Well Seal and Air Vent

SANITARY WELL SEAL

The top of a drilled well should be equipped with a sanitary well seal if the discharge lines of the pumping system pass through the top of the well casing (Figure 10). This is to prevent surface water or foreign materials from entering the well. The common type of well seal consists of a rubber disk sandwiched between two metal plates. The rubber and metal plates are made with several holes to accommodate the pump discharge pipe, cable conduits and air vent. The plates and rubber disk are held together by bolts which when tightened squeeze the rubber disk against the discharge pipe, the vent pipe and the side of the casing to make a watertight seal.

PITLESS ADAPTOR

Pitless adaptors (Figure 11) are specially designed connectors which provide a watertight seal where the discharge line passes through the wall of the well casing of a drilled well. The adaptor is easily disconnected, allowing the removal of the well pump and the pump column from the well. The adaptor facilitates well rehabilitation and pump replacement should the pump fail or require maintenance. Except where drilled wells are completed inside well pits, or bored or dug wells, the well casing of a drilled well must always be brought to surface, must extend 30 centimetres above ground surface and must *never* be cut off below ground surface and buried. The top of the casing must be covered with a well cap (Figure 11) to prevent the entry of surface water or foreign materials.

AIR VENT

An air vent (Figures 10-11) is necessary to equalize the air pressure between the inside of the well casing and the atmosphere and to release lighter than air noxious or explosive gases. If natural or other gases are present and released from the well water and the well is enclosed in a building or confined space, the air vent should always be extended to the outside atmosphere. In a well pit, the vent is required to be raised to within 15 centimetres or less of the top of the well pit (Figure 12). The vent pipe must be shielded and screened to prevent the entry of foreign material into the well and preferably it should be removable to allow water level measurements to be taken.

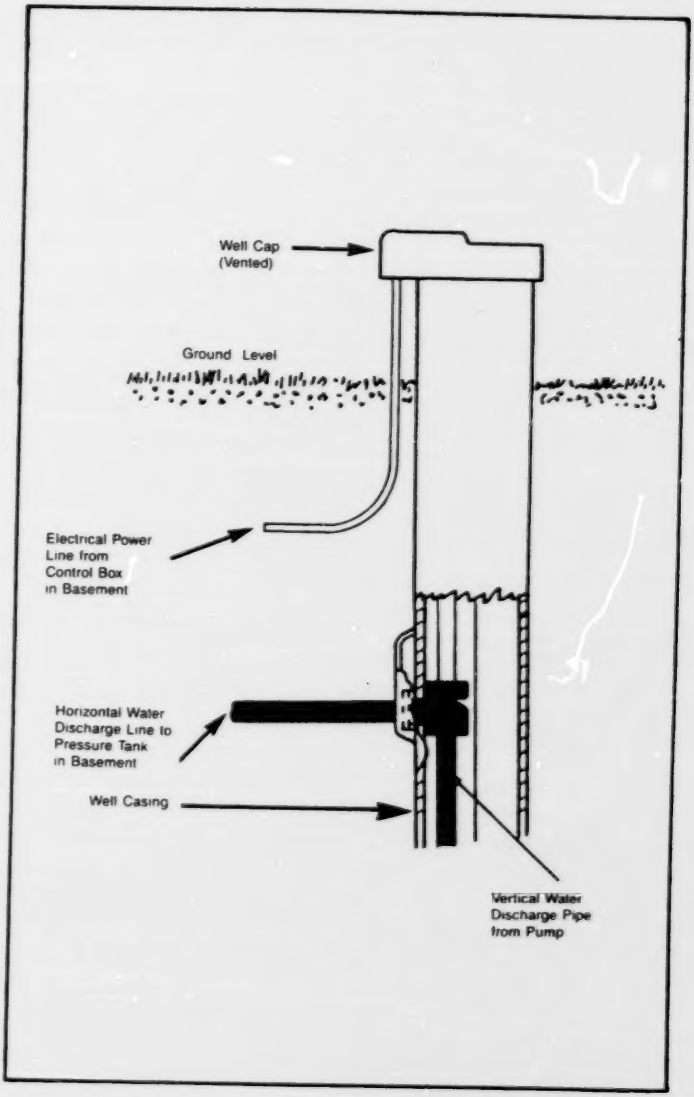


Figure 11. Pitless Adaptor

WELL PITS

Well pits (Figure 12) are lined, shallow excavations constructed around the top of the well head or well casing of a drilled well that allow access to the well for inspection, maintenance and repair. A well pit should not be constructed at sites where surface water or ground water is likely to seep into the pit and accumulate unless adequate drainage or an automatic sump pump is provided. The drain lines from the pit should be equipped with back-flow preventors. These precautions are necessary to prevent flooding of the pit and contamination of the well.

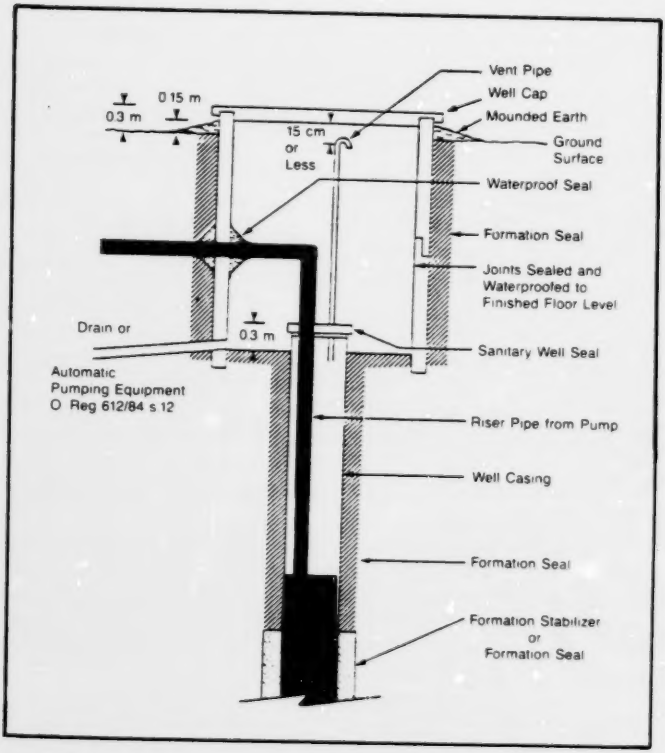


Figure 12. Well Pit Construction

The well pit should be watertight and must at all times be covered with a tight-fitting removable cap. If concrete tiles are used in the construction of the pit, the joints between the tiles must be grouted and properly sealed. All holes made through the sides of the pit wall (pump discharge line) should be sealed with a waterproof material. The walls of the pit must be at least 30 centimetres above ground level and should extend below the frost line.

The ground surface surrounding the perimeter of the wall of the pit should be raised and mounded to a height at least 0.15 metres above general ground level and sloped away from the pit to divert surface drainage. An annular seal is required. The material requirements for the seal should follow the recommendations for dug or bored wells in Ontario Regulation 612/84 (Figure 3b). The top of the well casing should be a minimum of 30 centimetres above the floor of the pit. The floor of the well pit must be at least 0.5 metres above the high water table level and it would be a good practice to construct the floor of the pit using clay or concrete.

The recommendations in the preceding section concerning the vent pipe should be followed and should there be any concern over possible well gases, a well pit should not be considered.

4. WELL WATER PUMPING SYSTEM

GENERAL

After the construction of the well, consideration is next given to the well water pumping system, the main components of which are the pump, pressure tank, controls and switches (Figure 13). The pumping system should supply water to the user at a near constant rate and pressure. The system needs to be carefully planned to ensure that both the immediate and foreseeable future water demands can be satisfied. The following sections describe the operation of the components of the system, the considerations which should be made in the selection of these components, and some of the common problems that may occur.

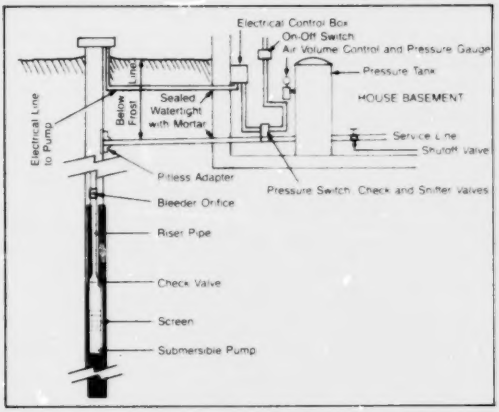


Figure 13. Complete Well Water Pumping System

WELL PUMPS

Pump Selection

The purpose of the pump is to lift water from the well and to deliver it to the pressure tank. There are several different types of pumps available for use in private water supply systems and to select the correct pump the following information is required:

1. safe or rated yield of the well
2. inside diameter and plumbness of the well
3. pumping water level

4. static water level
5. well depth
6. discharge pressure
7. water demand

The *safe* or *rated yield* of the well is the amount of water that the well will supply during a sustained period of usage without lowering the water level in the well to the pump intake. The safe yield varies considerably from well to well. Based on a short pumping test of the well, the well contractor will recommend a pumping rate and a depth setting for the pump and record them on the Water Well Record. The selected pump should have a capacity equal to or less than the recommended pumping rate. Equipping the well with a pump with a higher capacity might lower the water level to the pump intake causing the pump to break suction, and overheat and damage the pump motor. In addition, over-equipping the well might break down the well's development, cause the well to pump sand, and reduce the well's efficiency.

The inside diameter of the well casing will limit the diameter of the selected pump ejector, drop (intake) pipe(s) and foot valve that can be installed. The diameter of the well is recorded on the Water Well Record.

The straightness or plumbness of a deep well might have to be checked because should the pump, i.e., submersible, come into contact with the well casing or the wall of the drillhole (rock well) the pump could be damaged.

The *pumping level* is the depth from ground surface to the water level in the well measured when the pump is operating. Following the construction of a well, the well contractor is required to conduct a pumping test a minimum of one hour in duration with either a bailer or well pump or alternatively he may chose to monitor the recovery of the water level in the well after blowing the well with air. He will measure the pumping level at set time intervals during the test as well as measure the water level while the well is "at rest" (*static water level*). The difference between the static water level and the pumping level is called the *drawdown* in the well. These measurements are reported on the Water Well Record.

The practical maximum height that a pump will lift water by suction (difference in elevation between the pump and pumping level) is approx-

imately 6.7 metres. The type of pump, its mechanical condition, the temperature of the ground water can all affect the amount of suction lift. The 6.7 metre limit on suction lift divides pumps into shallow-well pumps and deep-well pumps. For example, if the pumping level in a well is 6.0 metres below the top of the well and the pump is installed at a location 3.0 metres higher in elevation than the top of the well, the total lift of the pump would be 9.0 metres; therefore, a deep-well pump would be required.

The *discharge pressure* (head) is the pressure expressed in kilopascals or metres of head of water at which water discharges from the pump. The pressure required at the pump discharge for a shallow-well pump or deep-well jet pump with pressure tank is equal to the cut-out pressure of the tank plus the height (elev.) of the tank above the pump and the friction losses in the pipeline between the pump and pressure tank.

Each kilopascal of pressure added to the discharge at the pump will raise water an additional 0.102 metres. Most water supply equipment dealers have tables from which the friction losses of the piping can be calculated. Each pound per square inch (psi) equals 6.89 kilopascals — see conversion table on page viii.

The *pump capacity* or *size required* is generally determined from the peak requirement rather than the total daily demand (see page 5). In the estimate, consideration must be given to the yield of the well established by the well contractor. Where the well yield is low, a larger than normal pressure tank with a large draw-off capacity and possibly a supplementary water storage tank may be necessary to meet the water requirements during periods of peak usage. The storage capacity of the well is also often considered in the sizing of the pump for a low-yielding well. Technical assistance from your pump supplier should be sought in these circumstances.

Where the well yield is sufficient, the pump capacity is also sometimes estimated by counting the maximum number of fixtures and water outlets in the house-barn which might be in use simultaneously and multiplying each by their respective flow rate. The flow rates for household fixtures are generally between 7.2 and 21.6 litres per minute and water supply equipment dealers have tables from which the flow rate per fixture can be determined (see also Table 1 for examples of farm requirements). For example, if it is anticipated that the demand

from 3 fixtures (dishwater [7.2 L/m], outdoor faucet [13.0 L/m] and washing machine [18.0 L/m]) will be placed on the well water pumping system at one time (peak demand), the pump capacity would have to be 38.2 litres per minute. If this requirement is maintained for 20 minutes, the pump would have to deliver 764 litres (38.2 litres per minute x 20 minutes) and be rated at 2292 litres per hour. Alternatively, the water supply system (pressure tank and well) would have to be capable of providing 2,292 litres per hour of water at a constant pressure. In addition to the peak domestic flows, separate consideration is usually given to lawn sprinkling which may require up to 1100 litres per hour on a lawn of 93 square metres. There are other methods that pump installers and suppliers use to determine the well pump capacity and you should seek assistance and thoroughly investigate your water requirements before purchasing a pump.

Pump Installation

Pump installation procedures vary considerably with the type of well pump selected. Some well contractors will supply and install pumps while others will subcontract the work. In some cases, you may have to hire a pump installer or plumber, who after April, 1989 will have to be licensed by the Ministry of the Environment to install or supervise the installation of pumps and related equipment in or connected to a well, Ontario Regulation 612/84, s.6 refers. You may also choose to install the pump yourself. Many pump manufacturers have installation booklets for the "do-it-yourselfer." These booklets are generally of a technical nature and are directed towards an individual with electrical and plumbing experience.

A number of items are common to most pump installations. These include:

1. proper pump housing and ventilation
2. proper pump maintenance and lubrication
3. overload protection, in either the form of fuses or circuit breakers
4. proper electrical wire sizes and connections
5. provision of lightning protection especially in the case of submersible pumps.

Shallow-Well Pumps

When a shallow-well pump (Figure 14) cuts in, it exhausts air from the pump drop pipe creating a vacuum into which the atmospheric pressure on the water outside of the drop pipe forces water to rise to the top of the drop pipe to start the pumping cycle. The maximum practical lift of a shallow-well pump is approximately 6.7 metres. At elevations above sea level, the air is less dense resulting in lower atmospheric pressure outside the drop pipe, reducing the amount of suction lift. This will limit the well yield and the amount of drawdown in the well.

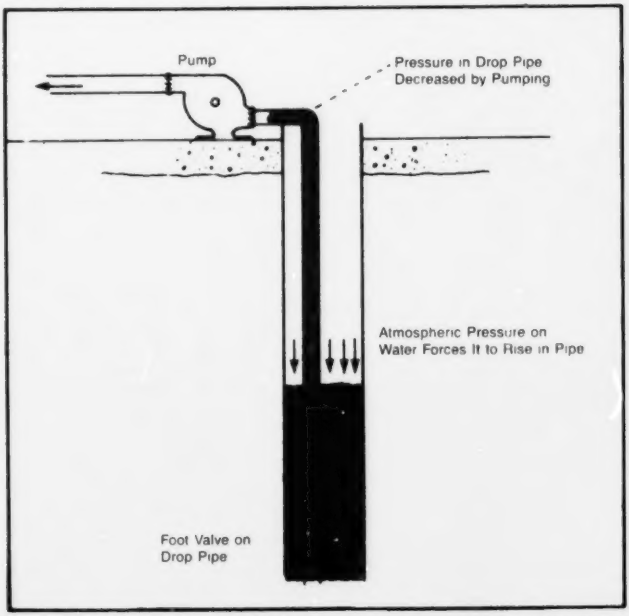


Figure 14. Shallow-Well Pump - Pump Suction Principle

Three common types of shallow-well pumps are listed below:

1. Reciprocating (piston) Pump - A vacuum is created by the movement of a piston inside a cylinder. Continuous repetition of the forward and reverse strokes results in a steady flow of water into the discharge pipe.

2. Centrifugal Pump - Water is propelled by centrifugal force by rotating impellers moving the water to the discharge pipe. The pump casing and the suction line must be kept full of water (primed) in order for the pump to operate.

3. Centrifugal-Jet Pump - This pump is similar to the centrifugal pump but the pressure (suction) in the pump is increased by forcing water through narrow jets. A smooth flow of water is supplied to the water pressure system, but the pump must be filled with water (primed) in order to operate.

Deep-Well Pumps

1. Reciprocating (Piston) Pump - This pump (Figure 15) consists of either a motor or a hand-powered mechanism located at the top of the well and a cylinder installed in the well casing.

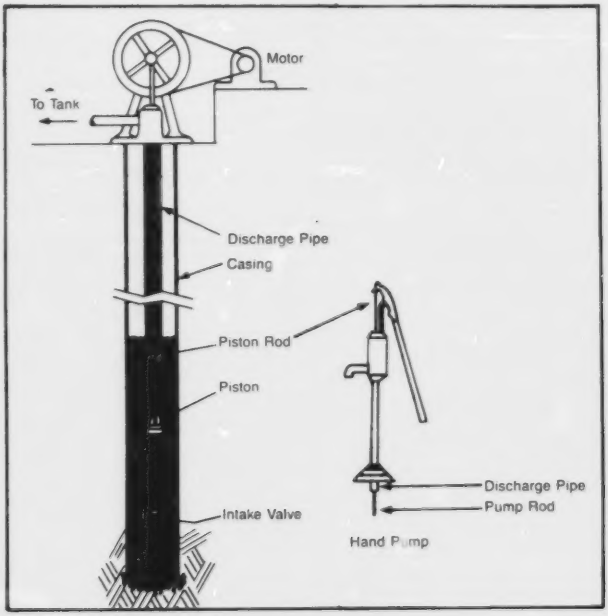


Figure 15. Deep-Well Piston Pumps

The motor or hand lever moves a piston in the cylinder up and down supplying a constant volume of water to the water distribution system. This type of pump can supply water from depths of 122 to 152 metres.

2. Deep-Well Jet Pump - This pump (Figure 16a) consists of a centrifugal pump unit (impeller) at ground level and an ejector assembly (Figure 16b) in the well casing above the intake. A drive pipe and a return pipe extend down the well from the pump to an ejector assembly. Another type is available for small diameter wells (50 mm, 64 mm and 76 mm) whereby a packer type ejector is used with only a return line running from the top of the casing to the ejector. The well casing is used to supply the water to operate the ejector.

   A deep-well jet pump can deliver water efficiently from about 30 metres. Greater depths are possible at the expense of reduced efficiency (at 30 metres, 75% of the water pumped is recycled to the ejector).

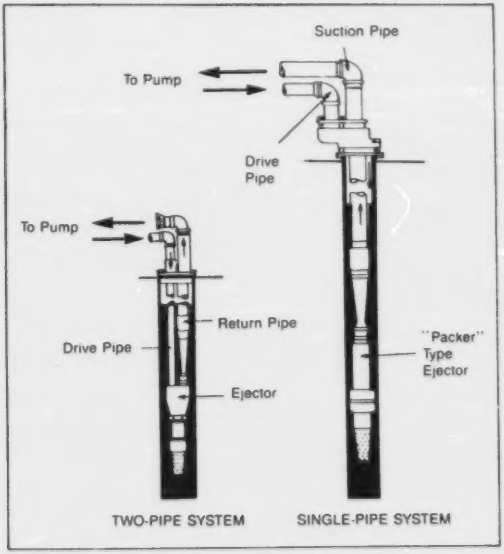


Figure 16a. Deep-Well Jet Pump System

3. Submersible Pump - The entire assembly of a submersible pump, (Figure 17) including the motor is placed below the water level in the well. The pump is connected to the surface by a discharge pipe and a waterproof electric cable from the motor. Submersible pumps can deliver water from depths to 300 metres. This is the most common type of pump used in deep wells in Ontario. It is not advisable to install a submersible pump if sand or gas are present in the water. The sand will abrade parts in the pump shortening its life while the gas in the water may cause the pump to lose its prime. In low yield wells, the installation of a flow control device may be necessary to maintain an adequate flow of water to cool the pump motor and to protect against possible burnout of the pump motor.

TABLE 3: THE ADVANTAGES AND DISADVANTAGES OF THREE COMMON TYPES OF PUMPS USED IN DOMESTIC WELLS.

ADVANTAGE	DISADVANTAGE
Reciprocating Pump	
1) Dependable, low cost, can be used in small diameter wells 2) Yields water at a constant rate and a high pressure 3) Easy to prime 4) Can pump small amounts of sand	1) Noisy with vibrations 2) Pulsating discharge
Jet Pump	
1) Low cost 2) High capacity at low total head 3) Can be converted to deep-well jet 4) Easy to service because of few moving parts 5) High pressure can be acquired with multistage units 6) Can be offset from well 7) Easy to install	1) Can't handle air in system 2) Needs large pipes 3) Difficult to prime if there is a leak in line 4) Requires high pressure pipe for multistage jet 5) Easily damaged by sandy water
Submersible Pump	
1) Very efficient, smooth, even flow 2) Has an excellent range in capacity and pressure 3) Long lines cause few problems 4) Constant capacity 5) No noise 6) Can be used for shallow or deep well 7) Free from freezing	1) Loss of prime can cause damage to motor 2) Not always easy to service and is expensive 3) Sand in water will wear pump parts 4) 75 millimetre diameter is smallest available 5) If screen becomes encrusted and flow is impaired the motor may burn out 6) Well must be plumb and free from obstructions

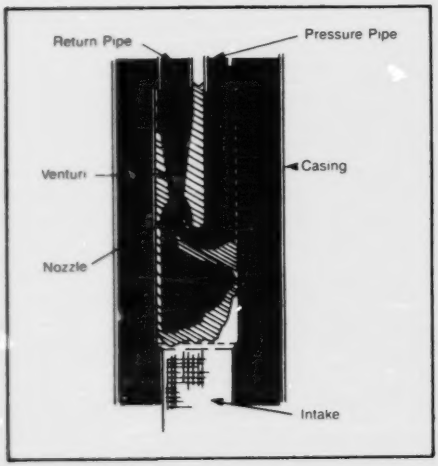


Figure 16b. Deep-Well Ejector Assembly

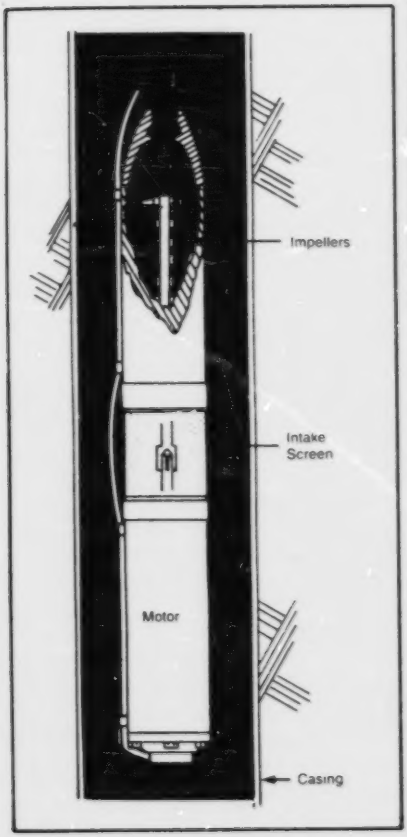


Figure 17. Submersible Pump

MOTOR AND ELECTRICAL SYSTEM

The power source for the pump motor is almost always electricity, but a pump can be operated by propane gas, gasoline and wind. Hand-operated pumps are still sold and are in use in Ontario at sites where there is no electricity or the water requirements are very small.

The type and size of motor needed to meet specific requirements for a particular pump are supplied by the pump manufacturer. The manufacturer's suggested maintenance requirements should be followed closely. Electrical problems can largely be avoided through the initial installation of adequate wiring and by continuous protection of this wiring. Protection is needed from damage due to overloading and from lightning. Lightning arrestors, proper grounding, and adequate fuses are all necessary.

PRESSURE TANK

The hydro-pneumatic water supply tank acts as both a water storage reservoir and a means of pressurizing the water supply system. By providing adequate water storage under air pressure the necessity of activating the pump each time a water faucet is opened is eliminated.

The well pump operates between two pressure-switch settings (draw-off capacity). When the pressure in a pressure tank drops to the lower pressure setting, the well pump cuts in and well water is pumped into the pressure tank. Air trapped in the top of the tank is compressed until the pressure in the tank reaches the upper pressure setting of the pressure switch and pumping stops. When a faucet or valve is opened, water is forced through the pipes by the air pressure in the tank. When the pressure falls below the lower pressure-switch setting, the pump cuts in and the cycle is repeated.

A conventional pressure tank will supply only about 15 per cent of the tank's volume between the pressure-switch settings. The draw-off capacity between 140 and 280 kPa can be increased to 18.3% of the tank volume by supercharging the pressure tank with air, 30% by using a float to separate air and water in the tank, and 36% by using a pressure tank with a bonded diaphragm or sealed bag.

It is important to note that a low yielding well may not be able to meet continuous demands on the system and the pressure in the system will not be able to be maintained by the pressure tank.

Air Volume Control

Since air is partially soluble in water, the air in a pressure tank will gradually dissolve in the water in the tank leading to a condition known as "water-logging" which results in rapid cycling of the well pump. There are four methods of controlling the amount of air in the pressure tank.

1. Air volume control: A float-operated valve fitted directly into a conventional pressure tank to maintain the correct relationship between the volume of air and the water level in the tank.

2. Supercharged Tanks: Tanks supercharged with air at pressures greater that atmospheric and maintained by a pressure-operated air charger.

3. Tank float: A circular disc floating on the water's surface which prevents the pressurized air in the tank from dissolving into the water by physically separating air and water. Some air will be dissolved over a period of time; therefore, tanks equipped with floats need to be recharged periodically.

4. Diaphragm tanks: A tank equipped with any sealed elastic diaphragm which separates the air and water. The air chamber is pre-pressurized and as the water level rises and falls in the tank, the air chamber contracts and expands, and does not need replenishing.

Ground water may sometimes contain very large quantities of naturally-occurring dissolved gases such as methane, hydrogen sulphide, etc. Because these potentially harmful gases may enter the pressure tank, the tank should be vented to the outside of the building (see Page 69).

Pressure Switch

The operation of a water system is controlled by a pressure switch which automatically starts and stops the well pump at specified tank pressures. The switch is pre-set at the factory and is usually set at a minimum nominal pressure of 140 kilopascals and a maximum nominal pressure of 280 kilopascals, but can be manually adjusted.

5. PROBLEMS WITH WELL WATER SUPPLIES

EQUIPMENT FAILURE

Water supply problems can be divided into two main categories, equipment failure and well failure. Most water-supply equipment dealers will provide, free of charge, technical information pamphlets on "trouble-shooting" of water supply equipment. In addition, it is a common practice to include operating instructions and parts lists with new equipment. These guides should be consulted when equipment failure occurs as many of the common problems can be corrected by such things as replacing a blown fuse, adjusting a pressure switch, or performing some other simple maintenance operation. Well failure problems are discussed below.

WELL FAILURE

Natural Lowering of the Water Table

Water levels in shallow dug and bored wells experience large fluctuations due to climatic conditions. In many cases, the natural seasonal change in water level may exceed a metre. Ground-water levels, in response to recharge to the aquifers (spring rains) are usually at their highest levels during April and May and then gradually decline until the latter part of September or the beginning of October. In the construction of a dug or bored well, the well casing should be set far enough below the water table to assure an adequate water supply during the dry summer periods when the water level declines.

Well Water Interference

The static water level in a well may be affected by large withdrawals of ground water from nearby large capacity wells or dewatering equipment for construction works. When a well is pumped, the water level in the immediate area of the well is lowered and a *cone of depression* develops around the well. The size and the shape of the cone will depend on the aquifer characteristics of the water-bearing formation in which the well is completed and the rate of pumping. An example of well interference is illustrated in Figure 18.

In the example, the operation of Well A develops a cone of depression which extends beyond Well B and results in the decline in the water level in Well B. Since the well pump in Well B is set near the bottom of the well, and the amount of interference is minimal, no effect on the

operation of Well B is observed. The cone of depression developed by pumping Well B lowers the water level in the aquifer below the pump intake of Well A and Well A's supply of water is interrupted. Water levels will return to normal in both wells once pumping has stopped or within some reasonable time afterwards. Water level recovery will depend on the quantity of water withdrawn from the aquifer and the length of time the well was pumped.

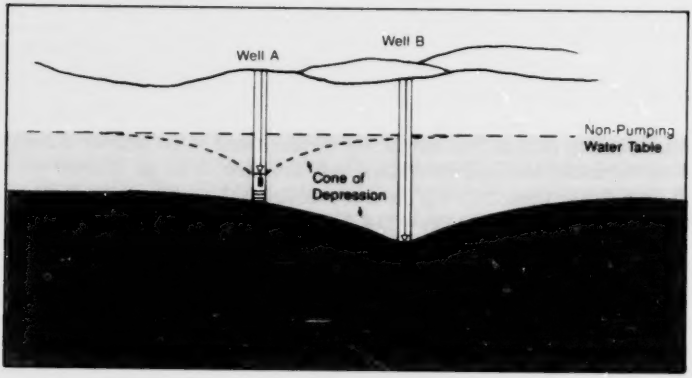


Figure 18. Cone of Depression - Well Interference

The construction of water and sewer mains, drainage ditches and highways (road cuts) can occasionally affect ground-water levels and interfere with nearby shallow wells.

Section 20 of the Ontario Water Resources Act requires that water supplies that have been interfered with as a result of a water taking under a Permit (see Page 6) issued by the Ministry of the Environment be restored. Should the interference be of a permanent nature, then the party causing the interference must restore the supply. Should the interference be of a temporary nature, the party causing the interference must provide an alternate supply for the duration of the interference.

In situations where you suspect that a water taking has lowered the water level in your well and has interrupted your supply, you should contact the Ministry of the Environment Regional Office (Appendix D).

The Regional Office will investigate your complaint, establish the source of the interference, and will attempt to resolve the problem.

Plugged Well Screens

Wells constructed in water-bearing formations containing clay, silt, or very fine-grained sand (quicksand) may produce some sand and the well water may be highly coloured or turbid.

The passage of these fine materials through a well screen may result in partial plugging of the screen and in the reduction in the quantity of water moving into the well thereby reducing well yield. Fine-grained particles will cause excessive wear on the moving parts (impellers) of a well pump and may plug pipes and the pressure tank.

If water-bearing silts or fine sands are encountered in an aquifer during well construction, the well contractor may drill deeper in an attempt to locate a coarser water-bearing horizon, rather than try to construct a well. He may also suggest, as a last alternative, drilling in another location and abandoning the well.

Some common causes of sand entering the well are the improper selection of the size of the openings of the well screen (slot size) and the incorrect positioning of the screen in the aquifer. In addition, proper development of the formation opposite the well screen is important in improving the sand-free quality of the well water and the water transmitting characteristics of the formation. Well development of existing wells can sometimes overcome sand problems and is an important operation in the construction of new wells. The methods of well development are outlined on Page 29.

In established wells the appearance of sand may indicate a corroded well screen, slotted pipe or straining device that has failed. It is possible, in some cases, to restore the well by installing a second well screen with a smaller slot size in the well, but it could be costly and might not be entirely successful.

Encrustation of Well Screens

Because the well screen is out of sight, it is often not considered until the well yield has decreased appreciably.

In highly mineralized waters, a well screen can sometimes become plugged through a buildup of deposits of magnesium or calcium carbonates, hydrated oxides or hydroxides, iron, and slime produced by

iron bacteria. These waters can cause *encrustation*, and decrease the well yield.

For example, some ground waters can be saturated with calcium and/or magnesium carbonate minerals so that any loss of carbon dioxide would initiate the deposition of these substances. Pumping operations that markedly lower the water pressure on the inside of the well screen or borehole as compared to the water-bearing formation itself, may release carbon dioxide in an effect not unlike releases from soda water. The resulting mineral deposit (similar to the scale that may form on the inside of a kettle) may thereupon clog the slots of the well screen and the formation adjacent to the well screen.

For this type of encrustation, the rate of clogging can often be reduced by decreasing the pumping rate and the attendant pressure across the well screen. Proper development of a well will increase the permeability of the formation around the well and in turn reduce the pressure gradient through increased well efficiency.

Muriatic acid (hydrochloric acid) or sulphuric acid are sometimes used to remove encrustations of magnesium, calcium and iron compounds from a well screen. You should never attempt to acidize your own well because of the danger in handling strong acid solutions and should leave this work to experienced well contractors. A strong concentration of chlorine up to 500 milligrams per litre (shock chlorination) is used to remove iron bacteria and slime deposits from the well screen; however, iron bacteria are seldom entirely eradicated and continued preventative maintenance is necessary.

It is a good idea to periodically check the performance of your well. This may be done by pumping the well at a constant pumping rate for a set interval of time (one hour, two hours, etc.). The static water level should be recorded prior to the test, and during the test several measurements of the pumping level should be taken. If the drawdown has noticably increased since the well was constructed or since the last performance check, then the well screen may be partially plugged. This test is routinely conducted by the well contractor during construction of a well and the final test results are reported in the Water Well Record.

Corrosion of Well Casing and Screens

Well water can be corrosive and can chemically attack the well casing and screen. Four common forms of chemical corrosion are: 1) direct chemical 2) dezincification 3) electrolytic 4) bacterial The destruction of the casing or screen by any of these processes will cause well failure.

1. Direct Chemical results from chemical interaction between ground water or soil and the metal of the casing, screen or pump. Corrosion of the well screen will enlarge the slot openings allowing fine-grained particles from the formation surrounding the screen to move into the well.

2. *Dezincification* consists in the removal of one of the metals in an alloy leaving the screen in its original shape but in a weakened, spongy form. Dezincification results from the electro-chemical difference in potential between the metals in the alloy.

3. *Electrolytic corrosion* results from the action of electrolytic cells formed between two different metals such as a well screen and its connectors . These metals act like a galvanic cell (battery) with one metal acting as the anode and another the cathode. A current is set up between the two metals resulting in the corrosion of the anode and deposition at the cathode.

4. *Bacterial corrosion* may be affected indirectly by biological infestations. Bacterial growths may alter some of the dissolved materials in ground water so that more rapid corrosion of casing or screens will occur. For example, from common calcium sulphate, sulphate-reducing bacteria may produce hydrogen sulphide and sulphuric acid. These compounds can greatly accelerate corrosion processes.

If ground water in your area is known to be corrosive, then increasing the wall thickness of the casing and pump column and using corrosion-resistant metals for the well screen and various parts of the pump is recommended. Your well contractor or pump installer may be able to offer advice on the presence of corrosive environments in your area.

6. FLOWING WELLS

While a flowing well has a certain aesthetic appeal, special precautions and construction techniques must be used to control the water pressure and flow or serious environmental problems can result. The free flow of excess water to waste can result in the depletion of a valuable resource and in unnecessary interference with other well supplies. Free flow from the well casing or a breakout of uncontrolled flow around the well casing can cause serious erosional and flooding problems on the owner's and adjacent properties that may be very difficult and costly to correct. Other construction complications include the prevention of contamination entering the over-flow pipe, the installation of pumping equipment, general well maintenance, and the eventual abandonment and plugging of the well.

The Ministry of the Environment to promote ground-water conservation and the prevention of possible environmental problems requires in Ontario Regulation 612/84 s.11(7) that when flowing artesian conditions are encountered and a flowing well is to be constructed and left in place, the person constructing the well (well contractor if by contract) must, by law, take certain actions. The well must be constructed and an appropriate discharge control device installed on the well casing in such a manner that:

a) The discharge of water from within any well casing can at any time be stopped or regulated.

b) There is no uncontrolled flow or leakage of water at any time at the well site from within the well casing or from around the outside of any well casing either to ground surface or to any other aquifer penetrated by the well.

If these requirements cannot be met for any reason, the person constructing the well must abandon the well in accordance with the plugging requirements in s.21(1) of the regulations.

The regulations stipulate that the costs of all work done in the prevention of uncontrolled flow and/or the abandonment of a flowing well shall be borne by the well contractor unless the well contractor is specifically released from that responsibility in a written contract with the homeowner. Under these circumstances the costs of the work of preventing uncontrolled flow at the site and/or of abandonment shall be borne by the homeowner. In either case, the contractor is responsible for completing all work in accordance with the regulation.

Flowing well problems and costly corrective actions can be prevented if proper investigative and construction procedures are followed.

Areas of potential flowing conditions can usually be identified through the investigation of existing sources of ground-water information such as, Ministry Water Well Record files, neighbourhood well owners, water well contractors, and Water Resources Bulletin 2-200 entitled *Flowing Wells in Ontario 1946-1976.*

Where flowing artesian conditions are expected, the placement of an adequate grout seal around the well casing in a manner consistent with the local hydrogeologic conditions is essential. A highly recommended construction procedure is to install and cement-in-place a protective casing, slightly larger in diameter than the finished well casing, from ground surface into the confining layer above the aquifer before proceeding with deeper drilling. This casing will provide a stable structure for the containment of flow and will prevent breakouts.

The abandonment of flowing wells is discussed in the Ministry of the Environment Facts sheet entitled "Recommended Methods for Plugging Abandoned Water Wells."

7. WATER QUALITY AND WATER QUALITY PROBLEMS

Almost all ground water originates as rain and infiltrates through the soil horizon to the underlying geologic formations (overburden or bedrock). The movement of water through the soil and the geologic formations will produce major changes in the chemistry of the water. These changes may be naturally-occurring or they may be the result of contamination of aquifers by nitrate, road salt, etc. Many naturally-occurring changes can affect the taste, odour, colour and general potability of well water. Treatment is possible for some of these problems.

The important thing to remember is that in Ontario different aquifers are likely to produce different quality waters, and that the quality may vary within the same aquifer. Wells screened at different depths are likely to produce different quality waters. As a general rule, the deeper a well is drilled in bedrock, the more likely it is to encounter water of a naturally poorer quality.

WATER SAMPLING AND ANALYSES

The following section outlines procedures for collecting well water samples, provides information on how to interpret the results of chemical and bacterial analyses, describes some of the common water quality problems (Table 4) encountered in water supplies and discusses the standard treatment methods to remedy these problems.

It is a good practice after the completion of a water well or when the quality of a water supply is suspect because of turbid water, unusual colour, taste or smell, to collect water samples and have them analyzed chemically and bacterially. The sampling procedures will vary with the water supply system; however, it is recommended that the following procedures be considered.

Chemical Analyses

Chemical analyses of water samples can be obtained from commercial laboratories and water-conditioning companies. These laboratories and companies are generally listed in the "yellow pages" of the phone directories.

Except when examining the specific performance of water treatment equipment, water samples should be obtained from a tap between the well pump and any water treatment units and/or the pressure tank. The tap should be open for at least five minutes before a sample is collected.

TABLE 4 COMMON WATER QUALITY PROBLEMS

PROBLEM	PROBABLE CAUSE	CORRECTIVE MEASURES
Mineral Scale build-up in kettles, water heaters and plumbing *Soap scum, excess soap consumption, dingy laundry, bath-tub ring*	Hardness (hard water)	(1) Water softeners (2) Soluble Phosphate Additives
Rusty to Black Stains on fixtures, laundry *Rusty to Black Water* *Metallic Taste*	Iron and/or manganese	(1) Aeration and settling or Filtration (2) Greensand/Potassium Permanganate ion-exchangers (3) Polyphosphate feeders (4) Water softeners (5) Chlorination-filtration units
Gastro - Intestinal Disease including typhoid fever, dysentery, diarrhea	Bacteria, viruses, or other micro-organisms	(1) Eliminate source of contamination and disinfect (2) Boiling (3) Super-chlorination/ dechlorination systems (4) Ultra-violet systems (5) Automatic Hypochlorination (6) Ozonation (7) Iodination (per MOH guideline)
Red to Brown Slime in toilet tanks and plumbing, reddish filament-like particles in water, *Reduced Well Yield*, sudden appearance of *Iron Staining* and *Unpleasant Taste or Odor*	Iron bacteria	(1) Chlorination-filtration units (2) "Shock chlorination" (see page 50) (3) Iodination (per MOH guidelines)
"Rotten-Egg" Smell and Taste, tarnishes silver and copper, corrodes plumbing	Hydrogen sulphide and/or sulphate-reducing bacteria	(1) Chlorination-filtration units (2) Greensand/permanganate ion-exchangers (3) Aeration
Salty Taste, corrosive	Chloride	(1) Reverse-osmosis units (2) Distillation
Offensive Odours, gas bubbles escaping from water	Gases (methane)	(1) Aeration (2) Activated carbon filters
Cloudy Water	Turbidity (clay)	(1) Filters (2) Alum treatment
Water has Laxative Effects	Sulphate	(1) Reverse-osmosis units
Petroleum Smells or Film on water	Gasoline and/or oil	(1) Activated carbon filters (assisted by preaeration) (2) Gravity-separation system
No Obvious Symptoms in adults but may cause a condition in formula-fed infants under 6 months called *methemo-globinemia* ("blue babies", in fact may die of asphyxiation)	Nitrate	(1) Reverse-osmosis units (2) Use nitrate-free water for infant formula preparation

For new wells, the well contractor will provide a water sample at the time the well is completed. It is suggested a sample be collected about 30 to 60 days after the well has been in use. This will ensure that the sample is representative of water in the aquifer.

The sample should be collected in a clean container, such as a new prescription bottle (sold in drug stores and obtained from water-quality laboratories) and should be at least 500 mL and preferably 1 litre in volume to provide the laboratory with sufficient sample for analysis. The container should be rinsed several times with the water to be sampled and should be filled completely and capped tightly to minimize oxidation effects. The laboratory may require the water sample to be fixed with a preservative. Deliver or ship the sample to the laboratory as quickly as possible so as to reduce the elapsed time between sampling and analyses, thereby reducing the possibility of any chemical changes in the water.

You should discuss with the local Medical Officer of Health, the Ministry of the Environment or a water conditioning company which parameters you should include in the analyses. The general characteristics of ground water can be obtained by using the list below. They are discussed in the following sections.

Chloride	Sulphate	Nitrate
Iron	Manganese	Hardness
Sodium	Conductivity	pH

Microbiological Analyses

Drinking water should be tested for the presence or absence of two groups of bacteria, total coliforms and fecal coliforms. These bacteria are considered to be "indicators" of the presence of animal wastes and sewage, in that they are present in large numbers in such wastes. Fecal coliforms are only found in the intestinal contents of humans and warm-blooded animals. They die fairly rapidly once outside the body; consequently, their presence in well water indicates relatively recent contamination and a short distance of travel. Water containing fecal coliform bacteria should not be consumed without adequate treatment e.g., boiling or disinfection.

The Ontario Ministry of Health will provide bacterial analyses of water supplies free-of-charge. The location of Regional Public Health Laboratories is provided in Appendix D.

Sterile bottles are available from either the Health Laboratories or local Health Units. Detailed sampling and handling instructions are included with the bottles. These instructions should be followed closely to prevent contamination of the sample. Bacteriological samples should be taken from the *treated* water supply used for potable purposes. A report will be returned to you with the results of the bacterial tests.

A water sample for microbiological analysis should be collected and analyzed:

1. after well completion and disinfection (before the well is used for drinking purposes)

2. one to three weeks after (1) to confirm acceptable results

3. when a well has not been in use for long periods (seasonal residences)

4. once or twice during the year, preferably after a heavy rain or periods of snow melt

Interpretation of the Chemical Analyses

The results of the chemical analyses of water samples are mainly reported in milligrams per litre (mg/L) and provide a numerical value representing the concentration of a particular parameter in a water sample. One mg/L is one milligram of substance per litre of water.

The Province of Ontario has established a comprehensive list of drinking water objectives for public drinking water supplies. These objectives are designed for the protection of public health. Any water that is intended for human consumption is not to contain any disease - causing organisms or hazardous concentrations of toxic chemicals or radioactive substances. Some of the objectives are based on aesthetic considerations such as taste, odour and colour.

Table 5 lists the "limits" for chemical parameters in public water supply systems expressed as the maximum acceptable concentrations (Parameters Related to Health) and the maximum desirable concentrations (Parameters Related to Aesthetic Quality). The tables are taken from the Ministry of the Environment's publication "Ontario Drinking Water Objectives" which provides considerable detail on the various parameters. It is desirable that the quality of water from private wells should meet these objectives.

TABLE 5: RECOMMENDED MAXIMUM ACCEPTABLE AND MAXIMUM DESIRABLE CONCENTRATIONS FOR DRINKING WATER PARAMETERS

(Ontario Drinking Water Objectives, Revised 1983)

TABLE 1
Maximum Acceptable Concentrations
Parameters Related to Health

Parameter*	Concentration (mg/L)
Arsenic	0.05
Barium	1.0
Boron	5.0
Cadmium	0.005
Chromium	0.05
Cyanide (Free)	0.2
Fluoride	2.4
Lead	0.05
Mercury	0.001
Nitrate (as N)**	10.0
Nitrite (as N)	1.0
Nitrilotriacetic Acid (NTA)	0.05

Parameter*	Concentration (mg/L)
Pesticides:	
(Aldrin + Dieldrin	0.0007
(Carbaryl	0.07
(Chlordane	0.007
(DDT	0.03
(Diazinon	0.014
(Endrin	0.0002
***(Heptachlor + Heptachlor Epoxide	0.003
(Lindane	0.004
(Methoxychlor	0.1
(Methyl Parathion	0.007
(Parathion	0.035
(Toxaphene	0.005
2,4-D	0.1
2,4,5-TP	0.01
Radionuclides****	—
Selenium	0.01
Silver	0.05
Trihalomethanes*****	0.35
Turbidity	1 FTU +

* Unless otherwise stated the limits for each substance refer to the sum of all forms present.

** Where both nitrate and nitrite are present, the total nitrate plus nitrite-nitrogen should not exceed 10 mg/L.

*** When more than one of these pesticides is present, the "total pesticides" shall not exceed the sum of their MAC's or 0.1 mg/L whichever is the lesser.

**** Maximum acceptable concentrations and target concentrations for radionuclides can be found in Table 3, section 2.4.

***** The term "trihalomethanes" comprises chloroform, bromodichloromethane, chlorodibromomethane, and bromoform, and their concentration as determined by the gas sparge or purge equivalent method (i.e. actual concentration) should not exceed 0.35 mg/L at any time.

+ Formazin Turbidity Units

TABLE 2
Maximum Desirable Concentrations
Parameters Related to Aesthetic Quality

Parameter	Concentration*
Chloride	250
Colour	5 (TCU) **
Copper	1.0
Iron	0.3
Manganese	0.05
Methane	3 L/m³
Odour	Inoffensive

Parameter	Concentration*
Organic Nitrogen***	0.15
Phenols	0.002
Sulphate	500
Sulphide	Inoffensive
Taste	Inoffensive
Temperature	15°C
Total Dissolved Solids	500
Total Organic Carbon	5.0
Zinc	5.0

* Unless otherwise indicated, the maximum desirable concentrations are expressed in mg/L.

** True Colour Units.

*** Total kjeldahl nitrogen minus ammonia nitrogen.

Sometimes the concentration of one or more chemical parameters exceed the recommended limits for drinking water. Dependent on which parameter is exceeded, you may be able to purchase a home water treatment device or a system of devices which will make your water safe and pleasant to drink (see Page 66). In some cases, the only alternative may be to replace the well supply. Advice on treatment can be obtained from water conditioning companies or from the local Ministry of the Environment office or the local Ministry of Health representative (Appendix D). It is generally possible to adopt some method of water treatment which will reduce the concentration of the "exceeded parameter" thereby improving the water quality.

Interpretation of the Microbiological Analyses

The microbiological (bacteriological) results are given in bacterial colony counts per 100 millilitres of sample. (See Table 6, Page 59, for an interpretation of microbiological analysis results provided by the Ministry of Health).

Remember that strict numerical limits for safety are difficult to establish, and that as the total number of coliform bacteria increases so does the risk of disease-causing organisms being present in the well water.

If coliform organisms are contained in the sample in numbers which indicate the supply is unsafe, the water should be chlorinated or boiled before ingestion and until further sampling indicates that the water is safe to use. The source of entry of the organisms into the well and well water should be determined and remedial measures taken to correct the problem.

Disinfection

Following unsatisfactory bacteriological reports, interim measures for using the available supply can be taken while awaiting confirmation of the initial test results or the installation of selected treatment equipment.

Chlorination of single batches of water (e.g., a litre of water) is relatively simple. Using an eye dropper, add two drops of household bleach (containing an average of 4% to 5% available chlorine — concentration, usually indicated on the label) to each litre of water. The water should then be stirred and left standing for at least 15 minutes before using. At the end of this time, the water should have a slight chlorine smell. If

TABLE 6: HOW TO INTERPRET A BACTERIOLOGICAL REPORT

COLIFORM BACTERIA per 100 mL		INTERPRETATION
TOTAL	FECAL	
> 160	> 60	Unsafe for drinking. This water is contaminated and should not be used for drinking under any circumstances. Do not attempt to apply these standards and interpretations to surface waters used for swimming.
10-160	1-60	Unsafe for drinking. Pollution source may be some distance from the water source, or diluted with large volumes of pure water, or the sample may not have been received within 48 hours of being taken. Samples older than 48 hours cannot provide reliable results.
10-160	0	Unsafe for drinking. Contamination is not likely to be of sewage origin unless far removed from the water source or unless there has been a delay in receipt of sample. Common with new wells before disinfection and shallow dug wells which are not properly sealed.
2-10	0	Doubtful for a single sample, but safe for drinking if condition remains stable and supply is protected and located at least 30 metres from any source of human or animal wastes
< 2	0	Safe for drinking. Repeat samples may not show exactly the same results because bacteria are not distributed uniformly in water, contamination tends to enter intermittently and numbers can change during sample transit time. Periodic sampling recommended.
Est		Unsafe for drinking. Number has been estimated due to some interference with the test. Exact number is not really critical, especially if in excess of limits shown above, for judging safety.
O/G		Doubtful condition and not recommended for drinking. No coliform bacteria could be detected because of "overgrowth" by other bacteria. This condition frequently occurs with new wells, dug wells receiving soil drainage, or wells which have been idle for some time. Collect another sample and identify clearly as a "REPEAT SAMPLE".

this is not the case, repeat the procedure. If the chlorine taste is too strong, the water can be left exposed to the air for a few hours before using.

Alternatively the water can be boiled. The water should be brought to a rolling boil for at least 5 minutes to kill any bacteria.

Various commerical water purifers are discussed in a later section.

A discussion of a method for chlorinating an existing well and water distribution system to 50 mg/L available chlorine is presented in Appendix E. For disinfecting a well currently in use with an unsatisfactory bacteriological report, 50 mg/L available chlorine is usually sufficient.

8. HOME TREATMENT DEVICES FOR SOME COMMON WATER QUALITY PROBLEMS

HARDNESS

Hardness or "hard water" as it is frequently called is a common characteristic of ground water in most areas of southern Ontario. Ground water as it moves through limestone bedrock or carbonate-rich overburden dissolves calcium and magnesium compounds which cause hardness. High hardness is a nuisance resulting in a scale formation on kettles, it prevents soap from lathering and it can result in a dingy laundry. Two common water-treatment processes exist which can be used as corrective measures; these are water softeners and soluble phosphate additives.

Water Softeners

In a softening unit (Figure 19), hardness is removed from water by a process called ion exchange. Water flows over an ion exchange resin (synthetic zeolite) that is charged with sodium ions. The calcium and magnesium ions in the water are traded for sodium ions, thus making the water soft. When most of the available sodium ions in the exchange resin have been replaced by calcium and magnesium, the unit must be regenerated with brine (concentrated salt solution). Some of the newer water softeners are fully automatic and regenerate themselves on a predetermined time cycle. Softeners are available in many sizes. Sizing is determined by the amount of water used, the hardness of the water and the frequency of regeneration.

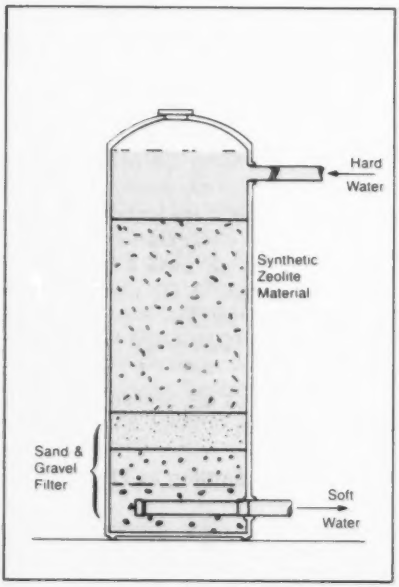


Figure 19. Water Softener

Water softeners increase the sodium content of the water up to 46 mg/L sodium for each 100 mg/L of hardness removed. Those individuals on a low sodium diet or with high blood pressure (hypertension) or heart disease should consult their physician before drinking softened water on a daily basis.

Soluble Phosphate Additives

Phosphate additives are available for water softening. These softeners are added to hard water to prevent it from reacting with soap or detergent to form a scum. These softeners help keep the carbonates in their dissolved form rather than remove them and thus a scale can still form in kettles, etc.

IRON AND MANGANESE

Ground water frequently contains iron and manganese in a colourless, dissolved form. Concentrations of iron in excess of 0.3 mg/L and manganese in excess of 0.05 mg/L are of concern for aesthetic reasons (see Table 5). When iron and manganese solutions come in contact with air (oxygen), the iron and manganese precipitate. This results in the staining of plumbing fixtures and laundry, and in discoloured or "rusty" water because of the presence of flakes of these metal oxides. Manganese stains are usually a blacker brown than those of iron and may be further distinguished by their ready solubility in mildly acidified hydrogen peroxide. Even a 50-50 mixture of vinegar and drugstore peroxide will remove the stains. Stronger reagents such as those for cleaning water softener resins may be needed for iron stains, particularly if they have been dried, heated or are considerably aged.

Several methods are available which either remove or control these metals — some of these are discussed below.

Aeration and Settling or Filtration

This method involves aerating the water in order to oxidize the iron and manganese, thus causing them to precipitate. The resulting precipitate is then either allowed to settle in a tank or is removed by filtering. This method is very effective; however, it may require additional chlorination to cope with excess bacteria introduced by aeration effects.

Greensand Filters

Greensand filters are an effective means for removing iron and manganese concentrations of up to 5-10 mg/L. The greensand media provides oxygen to the water passing through it. This oxidizes these metals resulting in their precipitation and filtration by the greensand. These filters need to be backwashed and have their oxygen supply regenerated on a regular basis in order to ensure their continued effectiveness. This is achieved by flushing with a large volume of water and then rinsing the greensand with a solution of potassium permanganate.

The well water system must be able to provide large volumes of water to backwash the filters. If such volumes cannot be provided it will be necessary to use one of the other treatment methods. The presence of iron or methane organisms in the water can cause a slime buildup on the greensand reducing its effectiveness. It may be necessary to chlorinate the water before it enters the filter to kill the bacteria.

Polyphosphate or Silicate Additions

Polyphosphate is effective in controlling iron and manganese concentrations of up to 2-5 mg/L. A concentrated solution of polyphosphate is added to the water supply by a chemical feeder. The polyphosphate stabilizes the metals, thus preventing them from oxidizing and coming out of solution. There are two limitations to this method; first it will only prevent the metals' ions which have not as yet been oxidized from oxidizing and second, the polyphosphate may break down when the water is heated in a water heater, thus reducing the effectiveness of the polyphosphate. Silicate solution addition works similarly, but requires a simultaneous chlorine treatment to work effectively. Treatment using liquid silicates with a ratio of 3.25 Si $0_2/Na_2$ 0 can achieve better stablization as is often the case with municipal supplies.

Water Softeners

Water softeners will remove concentrations up to 2 mg/L of iron and manganese from the water. It is necessary to maintain the metals in their dissolved forms, by keeping the oxidation to a minimum, otherwise the softener will rapidly become clogged. For this reason, it usually is preferable to remove iron and manganese from the water before it enters the softener. Should resins become filled with these minerals, proprietary formulations containing dithionate and bisulphite chemicals

may be obtained for occasional resin bed treatment to restore the operating capacity.

Chlorination-Filtration Units

Chlorine is a strong oxidizing agent and also acts as a disinfectant. The addition of a chlorine solution to the water will oxidize the iron and manganese causing it to precipitate. The water must then be passed through a filter such as sand to remove the metal precipitate. Wherever chlorine tastes and odours need removal, a bed of activated charcoal can be used following iron and manganese removal.

CHLORIDE, SULPHATE AND NITRATE

Ground waters with chloride and sulphate concentrations in excess of 250 mg/L and 500 mg/L respectively, and nitrates in excess of 10 mg/L as nitrogen are not desirable for domestic water supplies. High chloride concentrations are readily identifiable by a salty taste in the water. Drinking water with high chloride concentrations is not harmful to health; however, high chloride concentrations are nearly always accompanied by high sodium concentrations. Individuals on a low sodium diet or with high blood pressure (hypertension), renal, or heart disease should consult their physician before consuming water on a daily basis with sodium concentrations over 20 mg/L.

High sulphate concentrations in water produce harsh tastes and can have a laxative effect for individuals who are not accustomed to such waters.

High nitrate concentrations in water are often indicative of pollution. Nitrate is produced by bacterial action on human and barnyard waste, by fertilizers and by the decomposition of plant matter. The presence of fecal coliform bacteria in the water in addition to nitrate indicates that the source of nitrates is likely septic tanks, or cesspools or barnyard wastes. High nitrate content may cause an oxygen-starved condition in bottle-fed infants under 6 months known as methemoglobinemia. The Ministry of the Environment publication "Ontario Drinking Water Objectives" states that: "Nitrate poisoning from drinking water appears to be restricted to susceptible infants; older children and adults drinking the same water are unaffected. Most water-related cases of methemoglobinemia have been associated with the use of water containing more than 10 mg/L nitrate (as N)." Well water with 10 mg/L or more of nitrate

should not be used for mixing formula for bottle-fed infants under 6 months.

When the concentration of nitrate is high, the source of the problem should be identified and remedial measures taken wherever possible. Remedial measures may involve removing the source of the nitrates, providing better well protection and maintenance or possibly having a well replaced.

Chloride, sulphate and nitrate can be removed from the water supply by various demineralization processes, one of which is reverse-osmosis.

Reverse-Osmosis Units

In a reverse-osmosis unit, mineralized water is forced through a semi-permeable membrane. The membrane passes fresh water — the minerals are left behind. These units are generally expensive and will only treat a few litres of water per day, enough for drinking and cooking. If a larger supply of water is needed, it may be necessary to either find a new water source, or else add additional treatment units to the system.

BACTERIA, PROTOZOA AND VIRUSES

Only a few of the many different kinds of bacteria, protozoa and viruses are pathogenic (disease-causing). Ground water for the most part does not contain any of these harmful organisms unless it has become polluted by surface water or seepage from sewage facilities.

Well contractors are required under Ontario Regulation 612/84 to seal the upper portion of wells so that surface water or seepage from septic tanks, privies or cesspools cannot enter the well. Many wells, particularly those that are dug or bored become polluted because the upper portion of the well between the casing and the borehole is not carefully sealed. For additional information on sealing the annulus of wells (see Section 9 and Figures 3a and 3b).

The procedure for verifying whether your well water is bacterially safe to drink is discussed under the headings "Microbiological Analyses" (Page 55) and "Interpretation of Microbiological Analyses" (Page 58).

If the source of the contamination appears to be septic tank effluent or barnyard wastes, an alternative source of water supply should be found

or a commercial water purifier should be installed. The user is cautioned that such waters may also contain high nitrate concentrations. This should be verified especially where there are infants in the household. The equipment used to disinfect drinking water is discussed below.

Following the installation of a water treatment unit, the water should be retested to ensure that the unit is working properly.

Home Water Treatment Devices

The Ministry of the Environment has published a guideline entitled "Information on the Use of Home Water Treatment Devices" which discusses the integrity of water treatment devices and their claims for removal of health-related contaminants in drinking water. This guideline and a "companion" consumer bulletin sheet entitled "Water Fit to Drink" are available from your nearest office of the Ministry of the Environment. The bulletin sheet may also be obtained from the Ministry of Consumer and Commercial Relations.

IRON BACTERIA

Iron bacteria occur in ground water. They are non-injurious to health but are nuisance organisms that can cause plugging of water-bearing formations and well screen openings. Iron bacteria can be transported on drilling tools from one location to another. Well contractors are required to disinfect all new wells they construct and they should chlorinate any water used in preparing drilling fluids or in other construction purposes associated with the well.

Iron bacteria produce accumulations of slimy clogging masses and cause the precipitation of iron and manganese. The combined effect of the growth of these organisms and the deposition of iron can completely plug a well screen in a relatively short time.

Chlorine is an effective means of controlling iron bacteria. The chlorine kills the bacteria destroying the slime deposits on the well screens and in the surrounding aquifer but at a very slow rate, so prolonged exposure times are required (see Appendix E for instructions on chlorinating an existing well). Unfortunately, iron bacteria are difficult to eradicate permanently and treatment of the well may have to be repeated periodically. To rid a well of iron bacteria, you may have to hire a well contractor who is experienced in handling strong solutions of chlorine. Shock chlorination of the well with at least 500 mg/L available

chlorine is usually recommended. Chlorination-filtration units are effective in controlling iron bacteria in the distribution system.

HYDROGEN SULPHIDE AND SULPHATE-REDUCING BACTERIA

Hydrogen sulphide is a gas that can be recognized by its disagreeable "rotten-egg" odor. Water containing hydrogen sulphide is also corrosive and will attack the plumbing system.

Some ground water which contains natural concentrations of sulphate may also contain sulphate-reducing bacteria. These bacteria change the sulphate to corrosion-promoting hydrogen sulphide. Such sulphide may directly create substantial thicknesses of air-corrodable sulphides out of contacted metal surfaces, and may also revert back to corrosive sulphuric acid at susceptible air-interface surfaces. The formation of hydrogen sulphide and sulphuric acid makes the water more corrosive and speeds up the attack on metals.

Sulphate-reducing bacteria favour warmth and require no oxygen to live (anaerobically). Since hot water contains less oxygen than cold water, the bacteria can infest hot water tanks. Their presence can be suspected if a hydrogen sulphide "rotten-egg" odor is noted coming from the hot water taps only.

Chlorination-filtration is a satisfactory way of removing hydrogen sulphide from water (see Iron and Manganese, Page 62). The chlorine oxidizes the hydrogen sulphide and forms a precipitate of sulphur; it also removes any sulphur bacteria present in the water. The sulphur precipitate is removed by a sediment filter and excess chlorine in drinking water is removed by an activated carbon filter.

These bacteria and hydrogen sulphide may also be removed by superchlorination followed by dechlorination with a carbon filter. Bubbling air through the water and splash aeration (running water over baffles while it is exposed to the air) also helps to get rid of the hydrogen sulphide odor.

Table 7 from the Water Well Journal (July, 1979) presents advantages and disadvantages of various methods of treating hydrogen sulphide.

TABLE 7: CONVENTIONAL HYDROGEN SULPHIDE TREATMENT METHODS (WATER WELL JOURNAL - JULY, 1979)

METHOD	ADVANTAGES	DISADVANTAGES
Oxidizing filters (potasium permanganate) "greensand" filters	Can remove up to 6 mg/L of sulphide	Sulphur clogs filter
Chlorination	Quick and effective	Extra equipment needed. Potentially corrosive water produced. Chlorine residual taste.
Ozonation	Quick and effective	High initial cost
Aeration	No chemicals required	Prolonged contact times. Second tank required for repressurizing water. Space required for aeration units. Must be protected from freezing.
Activated carbon filtration	Removes mild taste and odor problems caused by H_2S	Useful only in concentrations less than 1 mg/L

GASOLINE AND OIL

Well contamination from the leakage or spillage of petroleum products is an extremely difficult and expensive problem to rectify because of the following characteristics of petroleum products:

1. They are relatively stable and will not readily decompose in the subsurface.

2. They are capable of travelling long distances with ground water, both as a liquid and in solution.

3. They will adhere to soil particles and be released only slowly by the flushing action of infiltrating precipitation.

4. They will release explosive vapors which for example are a concern when handling contaminated materials.

Small quantities of a petroleum product in water will affect its taste and odor and render it unfit for use. The best solution to this problem is one of prevention.

Where a leak or spill occurs or should a petroleum-like taste or odor be detected in a water supply, it should be reported immediately to the local Ministry of the Environment Regional Office. Depending on the local hydrogeology, the volume involved and the hydrocarbon concentrations, clean-up procedures can be very elaborate and costly. They may involve the excavation and removal of the contaminated soils to an approved landfill site or they may simply involve adding an activated carbon filter to the water distribution system. In many instances, maintaining aerobic conditions by frequent intermittent aerations down the well has been found useful for accelerating decontamination from hydrocarbon products.

GAS (METHANE)

Many water wells, particularly in southwestern Ontario, yield water containing some natural gas. Natural gas escaping into an enclosed well pit or pumphouse has been known to cause explosions and fires. A well containing natural gas should be sealed at the top and fitted with an air vent that dispels the gas into the atmosphere. The vent should be at least 2.5 metres above ground level.

Sometimes, if a strong flow of natural gas is encountered, it is necessary for well contractors to leave the well site for a short period during which time the gas is allowed to flow to the atmosphere unrestricted. Signs warning of the presence of explosive gas should be posted at the site. The presence of natural gases in a well should be recorded by the well contractor on the Water Well Record.

Natural gas may also cause well pumps to lose their prime. A gas separator diverting gas away from the pump intake will protect the pump and improve its operation (Figure 20). In addition, because all the gases may not be released immediately in the well, it may be necessary to vent the pressure tank, hot water tank or water treatment devices to the atmosphere to prevent a buildup of gases within the distribution system. Unreleased methane gas may impede oxidative water treatment processes i.e., the fouling of iron and manganese filtration units. The use of aeration and activated carbon filters will remove any gas which may enter the distribution system. Considerable care should be taken whenever work is done on a well that produces gas because of the possibility of an explosion.

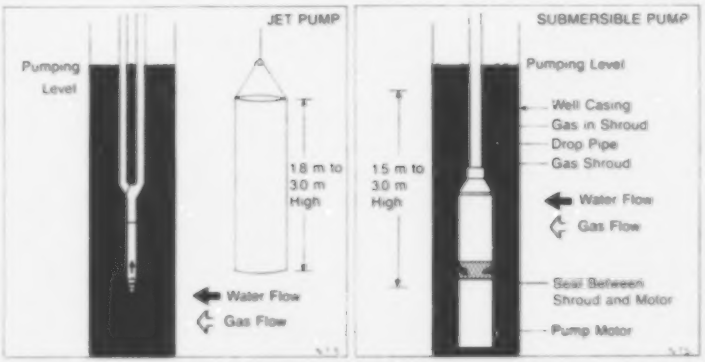


Figure 20. Gas Separators

TURBIDITY

In some new wells the water is turbid or cloudy. This results from a fine suspension of clay, silt or organic matter in the well water.

The particles should eventually settle to the bottom of the well. Pumping the well will develop it further and the problem should disappear. Where turbidity persists, it may be necessary to add a filter to remove the fine particles.

Filters

Sand and diatomite filters are commonly used to remove fine-grained particles in water. A diatomite filter consists of a filter cake of diatomaceous earth. Water is forced through the filter removing all turbidity. The filter should be backwashed regularly to maintain its effectiveness. Other filters which are used include, carbon cloth, porous stone, and paper. These filters come in cartridges which can be added to the water lines. The cartridge is replaced periodically. Most water conditioning companies carry a variety of filters and are a good source of information on turbidity related problems.

9. MAINTENANCE, RECONSTRUCTION AND REPAIRS TO EXISTING WELLS

Ontario Regulation 612/84, Section 20, pertaining to water well construction in Ontario states that: "The well owner shall maintain the well at all times after the completion date in a manner sufficient to prevent the entry into the well of surface water or other foreign materials."

A new well, pump and distribution system are expensive; therefore, care should be taken to maintain the existing system in a sanitary and serviceable condition. At regular intervals, the well and surroundings should be inspected to ensure that:

1. The well is fully accessible.

2. The sanitary well seal or well cap is securely in place and watertight.

3. No openings have developed in the well casing, or between the joints of cement-tile casings due to subsidence, corrosion, or damage that could allow surface water and debris to enter the well.

4. The annular space around the well casing is filled with either cement grout, concrete, bentonite or equivalent commercial slurry or clay slurry to prevent surface water from seeping around the casing and into the well.

5. Surface-water drainage in the vicinity of the well is directed away from the well and does not collect or pond in the vicinity of the well.

6. The sanitary well seal or well cap is at least 30 cm above ground surface and the well casing is not cut off and buried.

7. The air vent is unobstructed.

8. The well casing connection between discharge line and pump drop pipe is watertight and the casing properly sealed.

9. Debris is not floating on the surface of the well water.

10. The well is not located near any potential source of pollution such as, refuse, petroleum, a chemical or salt storage facility, etc., and that no activities are taking place near the well that could contaminate the well and the aquifer.

11. The annulus around the well pit casing is properly sealed and the well pit properly drained.

12. Where an abandoned bored or dug well serves as a well pit for a drilled well then:

    a. the above precautions should be followed

    b. the annular space between the well casing and formation(s) around the dug or bored well must be effectively sealed so that there is no water standing in the pit at any time of the year; otherwise provision should be made for gravity drainage or automatic pumping equipment in the well pit

The well pump and distribution system equipment should be serviced as specified in the manufacturers' service manuals. Exposed wiring, frayed contacts, damp or wet conditions and other potentially hazardous situations should be corrected as noticed.

Conditions such as reduced well yield, sand in the water, and certain common water quality and water distribution problems discussed elsewhere in the text should be investigated.

More details on the maintenance of dug, bored or drilled wells are provided in the Ministry of the Environment Facts sheets entitled:

"Protection of Water Quality in Drilled Wells", July, 1986
"Protection of Water Quality in Bored and Dug Wells", July, 1986

These Facts sheets are available at any Ministry of the Environment Regional or District Office.

10. WELL ABANDONMENT

Ontario Regulation 612/84 places legal responsibility for the plugging of abandoned wells onto the well owner. Section 21 states: "When a well is to be abandoned, it shall be plugged with concrete or other suitable material so as to preclude the vertical movement of water or gas in the well between aquifers or between an aquifer and the ground surface."

Improperly abandoned wells are a hazard to public health and physical safety. Abandoned wells should be carefully sealed to prevent pollution of ground water, to conserve aquifer yield and artesian pressure (particularly in the case of flowing wells), and to prevent poor quality ground water from moving between water-bearing zones.

A Facts sheet entitled "Recommended Methods for Plugging Abandoned Water Wells" September, 1986 is available upon request from the Ministry of the Environment. Anyone planning to abandon a well should read this information brochure. Employment of a well contractor familiar with abandonment procedures is particularly advisable in cases of deep, or flowing wells, or wells in fractured bedrock.

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United States Environmental Protection Agency, 1976. Manual of Water Well Construction Practices; EPA-570/9-75-001, Washington, D.C.

United States Department of the Interior, 1977. Ground Water Manual; Bureau of Reclaimation, Washington, D.C.

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LIST OF SELECTED ONTARIO MINISTRY OF THE ENVIRONMENT PUBLICATIONS REFERENCED IN THE TEXT

Cottage Country; An Environmental Manual For The Cottager; Fourth Edition, 1986.

Facts Sheet - Protection of Water Quality in Drilled Wells; July, 1986.

Facts Sheet - Protection of Water Quality in Bored and Dug Wells; July, 1986.

Facts Sheet - Recommended Methods for Plugging Abandoned Water Wells; September, 1986.

Information on the Use of Home Water Treatment Devices; 1986.

Ontario Drinking Water Objectives; Revised 1983.

Water Fit to Drink; 1986.

Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment; Revised 1984.

APPENDIX A
GROUND-WATER PUBLICATION LIST OF THE WATER RESOURCES BRANCH OF THE MINISTRY OF THE ENVIRONMENT WITH LOCATION MAPS

PUBLICATION NO.	SERIES AND TITLE	MICROFICHE NO.
	Water Resources Reports	
1	Water Resources of the Big Otter Creek Drainage Basin(s), by U. Sibul, 91 pp. (1969).	256-79
2	Water Resources of the Big Creek Drainage Basin, by T.J. Yakutchik and W. Lammers, 172 pp. (1970).	257-79
3	Water Resources of the Upper Nottawasaga River Drainage Basin, by U. Sibul, K. Goff and A.V. Choo-Ying, 128 pp. (1971).	258-79
4	Evaluation of the Ground Water Storage Capacity in the Soper Creek Sub-basin Using the Physical Parametric Approach, by M. Barouch, 45 pp. (1971).	242-79
5b	The Hydrogeology of the IFYGL Forty Mile and Oakville Creeks Study Areas, by R.C. Ostry, 44 pp. (1979).	259-79
5c	The Hydrogeology of the IFYGL Duffins Creek Study Area, by R.C. Ostry, 39 pp. (1979).	487-79
5d	A Hydrogeological Study along the North Shore of Lake Ontario in the Bowmanville-Newcastle Area, by S.N. Singer, 72 pp. (1974).	75-0422
5e	The Hydrogeology of the IFYGL Moira River, Wilton Creek and The Thousand Islands Study Areas, by R.C. Ostry, 40 pp. (1981).	972-81
6	Water Resources of the Moira River Drainage Basin, by U. Sibul, K. Goff and A.V. Choo-Ying, 115 pp. (1974).	260-79
7	Geology and Ground Water Resources of the Wilton Creek IHD Representative Drainage Basin, by Gunther Funk, 96 pp. (1977).	261-79
8	Ground Water Resources of the Duffins Creek-Rouge River Drainage Basins, by U. Sibul, K.T. Wang and D.J. Vallery, 109 pp. (1978).	262-79
9a	Geology and Water Resources of the Bowmanville, Soper and Wilmot Creeks IHD Representative Drainage Basin, by Gunther Funk, 113 pp. (1977).	263-79

PUBLICATION NO.	SERIES AND TITLE	MICROFICHE NO.
	Water Resources Reports (cont'd)	
9b	Evaluation of the Ground Water Responses Applied to the Bowmanville Soper and Wilmot Creeks IHD Representative Drainage Basin, by Gunther Funk, 233 pp. (1977).	1585-82
10	Hydrogeology and Ground Water Model of the Blue Springs Creek I.H.D. Representative Drainage Basin, by J.M.H. Coward and M. Barouch, 108 pp. (1978).	264-79
11a	Northern Ontario Water Resources Studies, General Characteristics and Frequency Analyses of Streamflows, by V.I. Chin and J.D. Eddie (1978).	265-79
11b	Northern Ontario Water Resources Studies, Ground-Water Resources, by K.T. Wang and V.I. Chin, 121 pp. (1978).	266-79
11c	Northern Ontario Water Resources Studies, The Water Quality of Selected Lakes in the Arctic Watershed of Ontario, by A.C. Roy, 95 pp. (1979).	267-79
12	Geology and Water Resources of the East and Middle Oakville Creeks IHD Representative Drainage Basin, by Gunther Funk, 68 pp. (1979).	629-80
13	Water Resources of the South Nation River Basin by V.I. Chin, K.T. Wang and D.J. Vallery (1980).	759-80
14	Ground Water Resources of the Thames River Basin by K. Goff and D.R. Brown (1981).	1623-82
15	Water Resources of the Holland and Black River Basins by D.J. Vallery, K.T. Wang and V.I. Chin (1982).	1993-83
	Technical Report Series	
10	Ground-Water Resources in the Grand River Basin by U. Sibul, D. Walmsley, and R. Szudy (1980).	954-81
	Water Resources Bulletins	
1	Ground Water in Ontario 1953 and 1954, 1961, 302 pp.	213-79
2	Ground Water in Ontario 1955 and 1956, 1963, 377 pp.	214-79
3	Ground Water in Ontario 1957, 1965, 205 pp.	215-79
4	Ground Water in Ontario 1958, 1966, 377 pp.	216-79

PUBLICATION NO.	SERIES AND TITLE	MICROFICHE NO.
	Water Resources Bulletins (cont'd)	
5	Ground Water in Ontario 1959, 1966, 320 pp.	217-79
6	Ground Water in Ontario, Southwestern Area 1960-1963, 1968, 485 pp.	218-79
2-7	Ground Water in Ontario, South Central Area 1960-64, 1969, 605 pp.	219-79
2-8	Ground Water in Ontario, Southeastern Area 1960-64, 1970, 307 pp.	220-79
2-9	Water Well Records for Ontario, Northern Area 1946-69, 1972, 617 pp.	221-79
2-10	Ground Water in Ontario, Southwestern Area 1964-67, 1970, 538 pp.	222-79
2-11	Ground Water in Ontario, South Central Area, 1965-67, 1971, 408 pp.	223-79
2-12	Water Well Records for Ontario - Durham, Northumberland, Victoria, 1946-69, 1975, 452 pp.	200-79
2-13	Water Well Records for Ontario - Haliburton, Peterborough, 1946-69, 1974, 278 pp.	74-0190
2-14	Water Well Records for Ontario - Hastings, Lennox and Addington, Prince Edward, 1946-1972, 1976, 491 pp.	201-79
2-15	Water Well Records for Ontario - Frontenac, Lanark, Renfrew, 1946-69, 1974, 403 pp.	202-79
2-16	Water Well Records for Ontario - Regional Municipality of Ottawa-Carleton, 1946-1972, 1976, 553 pp.	203-79
2-17	Water Well Records for Ontario - Leeds and Grenville, 1946-1972, 1976, 311 pp.	204-79
2-18	Water Well Records for Ontario - Dundas, Glengarry, Prescott, Russell, Stormont, 1946-1972, 1977, 263 pp.	205-79
2-19	Water Well Records for Ontario - Essex, 1946-1974, 1977, 223 pp.	206-79
2-20	Water Well Records for Ontario - Kent and Lambton, 1946-1974, 1977, 608 pp.	207-79

PUBLICATION NO.	SERIES AND TITLE	MICROFICHE NO.
	Water Resources Bulletins (cont'd)	
2-21	Water Well Records for Ontario - Regional Municipalities of Halton and Peel, 1978, 501 pp.	208-79
2-22	Water Well Records for Ontario - Elgin, Middlesex, 1946-1975, 1978, 609 pp.	209-79
2-23	Water Well Records for Ontario - Regional Municipality of Haldimand-Norfolk, 1946-1975, 1978, 273 pp.	210-79
2-24	Water Well Records for Ontario - Huron, Oxford, Perth, 1946-1976, 1979, 641 pp.	486-79
2-25	Water Well Records for Ontario - Bruce, Dufferin and Grey, 1946-1977, 1981, 674 pp.	846-81
2-26	Water Well Records for Ontario - Waterloo, Wellington, 1946-1977, 1981, 663 pp.	922-81
2-27	Water Well Records for Ontario - Simcoe, 1946-1977, 1981, 504 pp.	1301-81
2-28	Water Well Records for Ontario - Regional Municipality of Niagara, 1946-1979, 1981, 153 pp.	1458-82
2-29	Water Well Records for Ontario - Brant, Hamilton, Wentworth, 1946-1979, 319 pp.	1839-82
2-30	Water Well Records for Ontario - Regional of York, (including Metropolitan Toronto) 1946-1979, 492 pp.	2036-83
2-31	Water Wells for Ontario - Regional Municipality of Durham, 1946-1980, 301 pp.	2772-84
	Atlas of Observation Wells in Ontario, 1980.	5017-85
2-101	Data for Observation Wells in Ontario 1974	211-79
2-102	Data for Observation Wells in Ontario 1975	212-79
2-103	Data for Observation Wells in Ontario 1976	166-79
2-104	Data for Observation Wells in Ontario 1977	336-79
2-105	Data for Observation Wells in Ontario 1978	550-80
2-106	Data for Observation Wells in Ontario 1979	970-81
2-107	Data for Observation Wells in Ontario 1980	1840-82
2-200	Flowing Wells in Ontario, 1946-1976.	5072-85

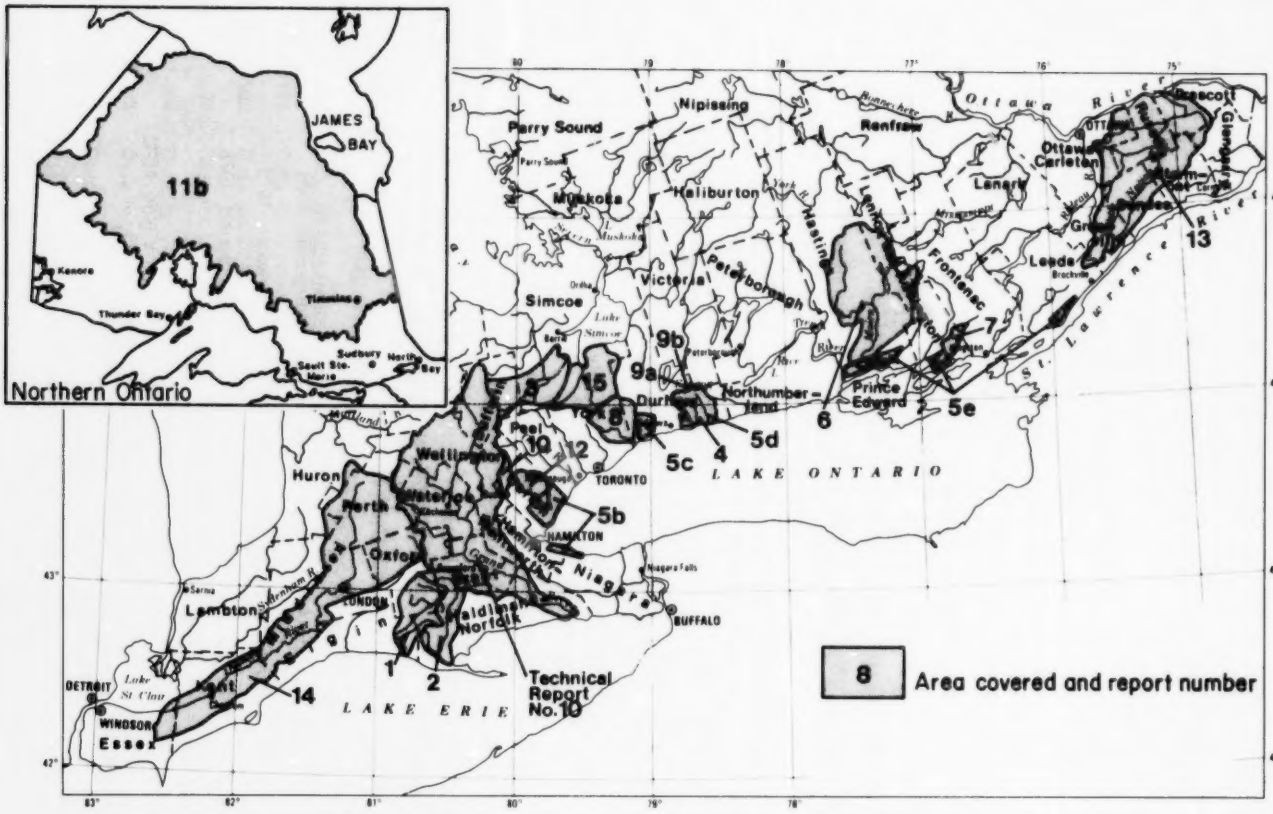
PUBLICATION NO.	SERIES AND TITLE	MICROFICHE NO.

Ground-Water Probability Map Series

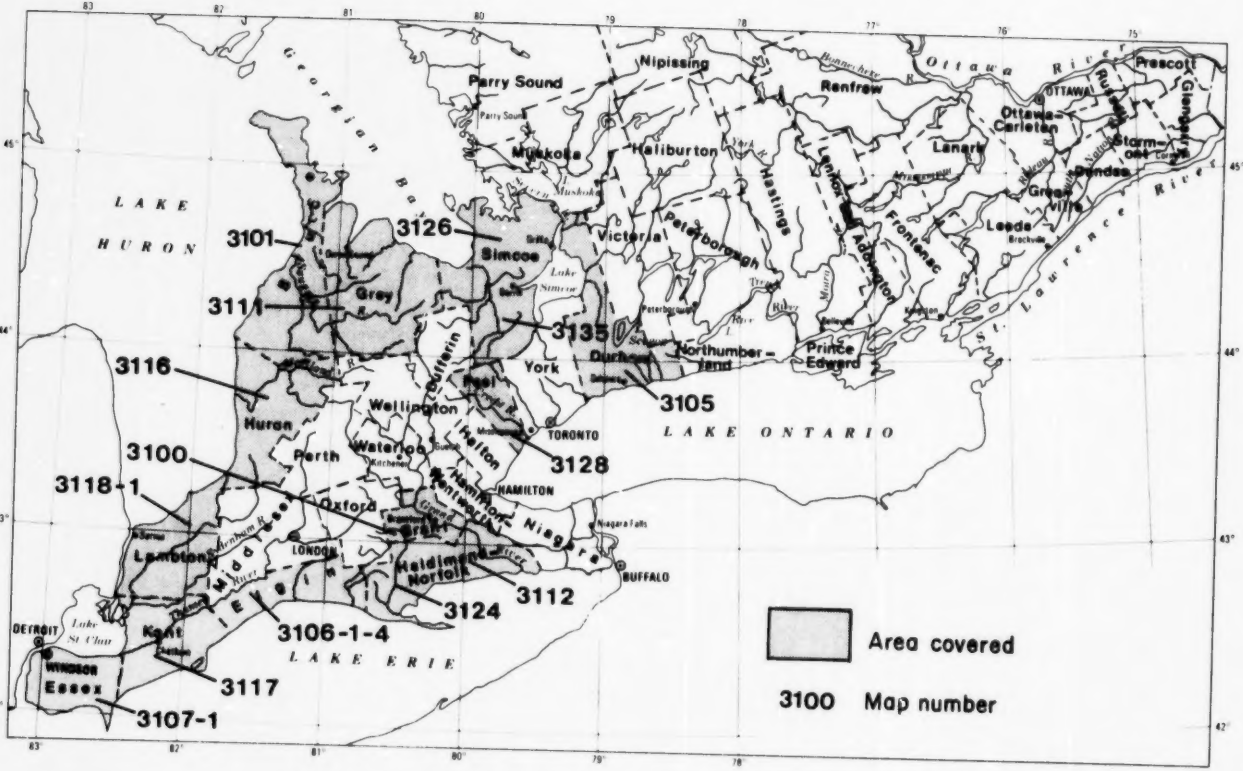
3100	Ground Water Probability, County of Brant, 1977
3106-1-4	Ground Water Probability, County of Elgin, 1972
3107-1	Ground Water Probability, County of Essex, 1971
3111	Ground Water Probability, County of Grey, 1984
3112	Ground Water Probability, County of Haldimand, 1974
3116	Ground Water Probability, County of Huron, 1986
3117	Ground Water Probability, County of Kent, 1969
3118-1	Ground Water Probability, County of Lambton, 1970
3124	Ground Water Probability, Region of Haldimand-Norfolk Western Portion), 1979
3128	Ground Water Probability, Regional Municipality of Peel, 1979
3126	Ground Water Probability, County of Simcoe (Northern Portion) 1982
3135	Ground Water Probability, County of Simcoe (Southern Portion) 1981
3101	Ground-Water Probability, County of Bruce 1986
3105	Ground-Water Probability, Regional Municipality of Durham 1986

Major Aquifers in Ontario Map Series

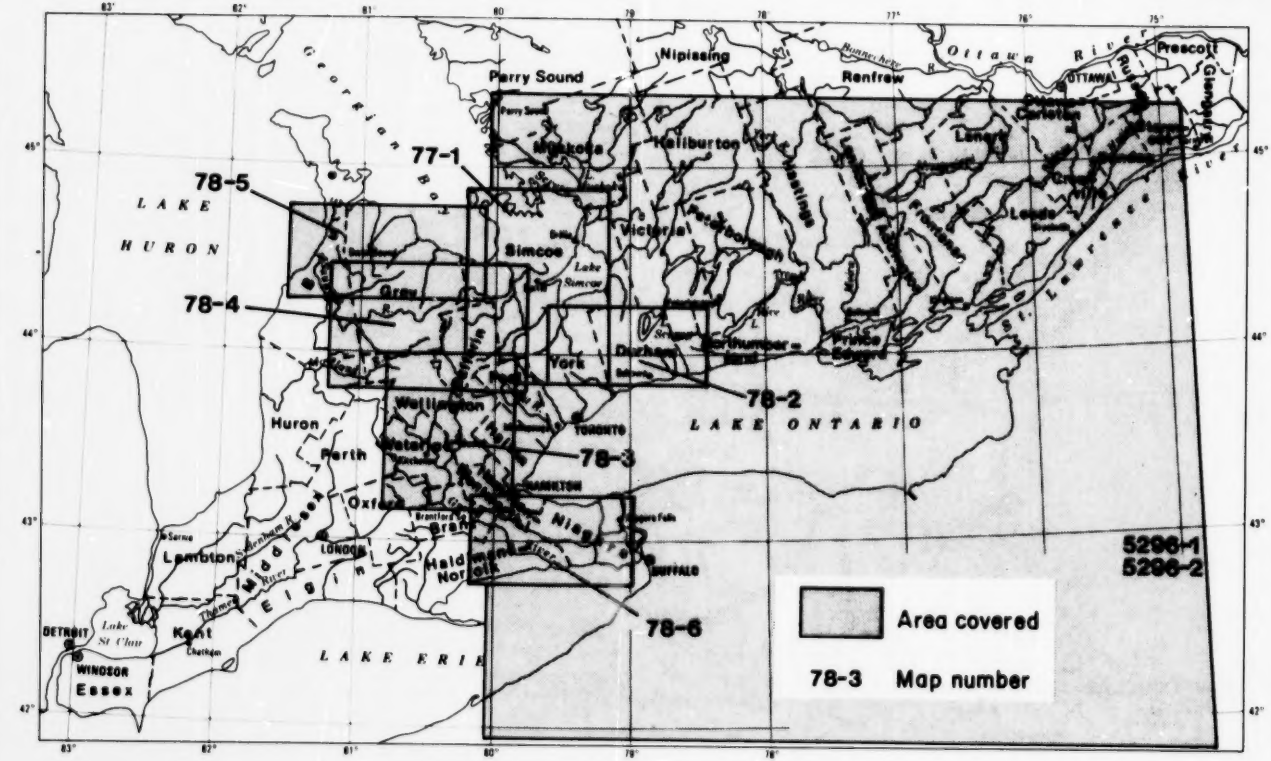
77-1	Alliston Aquifer Complex, 1977
78-2	Oak Ridges Aquifer Complex, 1977
78-3	Guelph-Amabel Aquifer, Hamilton to Orangeville, 1978
78-4	Guelph-Amabel Aquifer, Orangeville to Markdale, 1978
78-5	Guelph-Amabel Aquifer, Markdale to Owen Sound, 1978
78-6	Guelph-Lockport Aquifer, 1978
5926-1	Lake Ontario Drainage Basin—Bedrock Well Yields, 1970
5926-2	Lake Ontario Drainage Basin—Overburden Well Yields,1973



INDEX TO WATER RESOURCES REPORTS



INDEX TO GROUND-WATER PROBABILITY MAP SERIES



INDEX TO MAJOR AQUIFER MAP SERIES

APPENDIX B WATER WELL RECORD FORM

Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1 PRINT ONLY IN SPACES PROVIDED
2 CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY OR DISTRICT | TOWNSHIP BOROUGH CITY TOWN VILLAGE | CON. BLOCK TRACT SURVEY ETC. | LOT

DRILLED (OR DUG) | ADDRESS | DATE COMPLETED

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO

WATER RECORD

WATER FOUND AT FEET | KIND OF WATER

☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL ☐ GAS

☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL ☐ GAS

☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL ☐ GAS

☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL ☐ GAS

☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL ☐ GAS

CASING & OPEN HOLE RECORD

INSIDE DIAM. INCHES | MATERIAL | WALL THICKNESS INCHES | DEPTH - FEET FROM | TO

☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE ☐ PLASTIC

☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE ☐ PLASTIC

☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE ☐ PLASTIC

SCREEN

SLOT NO. OF OPENING | DIAMETER | LENGTH

INCHES | FEET

MATERIAL AND TYPE | DEPTH TO TOP OF SCREEN FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM | TO | MATERIAL AND TYPE | AMOUNT (CEMENT GROUT, CLAY PACKER ETC.)

PUMPING TEST

PUMPING TEST METHOD ☐ PUMP ☐ BAILED

PUMPING RATE GPM | DURATION OF PUMPING HOURS MINS

STATIC LEVEL FEET | WATER LEVEL END OF PUMPING FEET

WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY

TIME MINUTES	FEET	TIME MINUTES	FEET	TIME MINUTES	FEET	TIME MINUTES	FEET

IF FLOWING GIVE RATE | PUMP SETTING SET AT FEET | WATER AT END OF TEST ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE GPM | RECOMMENDED PUMP SETTING FEET | RECOMMENDED PUMPING RATE GPM

☐ SHALLOW ☐ DEEP

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE INDICATE NORTH BY ARROW

DRILLING READINGS

FINAL STATUS OF WELL

☐ WATER SUPPLY ☐ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED INSUFFICIENT SUPPLY ☐ ABANDONED POOR QUALITY ☐ UNFINISHED ☐ DEWATERING

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF CONSTRUCTION

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☐ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIGGING ☐ JETTING ☐ DRIVING ☐ DIGGING ☐ OTHER

CONTRACTOR

NAME OF WELL CONTRACTOR | WELL CONTRACTOR'S LICENCE NUMBER

ADDRESS

NAME OF WELL TECHNICIAN | WELL TECHNICIAN'S LICENCE NUMBER

SIGNATURE OF TECHNICIAN/CONTRACTOR | SUBMISSION DATE DAY MO YR

OFFICE USE ONLY

OWNER'S COPY

FORM NO. 0506 (77/06) FORM 9

Water Well Record Form cont'd

THE ONTARIO WATER RESOURCES ACT AND REGULATION 612/84

CERTAIN SECTIONS OF THE ONTARIO WATER RESOURCES ACT ARE OF INTEREST TO WELL OWNERS. PARTS OF THESE ARE DESCRIBED BELOW FOR YOUR INFORMATION.

1 UNDER SECTION 16 (1)

1 UNDER SECTION 16 (1)	NO PERSON SHALL DISCHARGE OR DEPOSIT ANY MATERIAL DIRECTLY INTO ANY WELL OR IN ANY PLACE THAT MAY IMPAIR THE QUALITY OF THE WATER IN A WELL.
2 UNDER SECTION 20 (3)	NO PERSON SHALL TAKE MORE THAN 10,000 GALLONS OF WATER IN A DAY FOR PURPOSES OTHER THAN DOMESTIC, FARM OR FIRE FIGHTING WITHOUT A PERMIT ISSUED BY A DIRECTOR OF THE MINISTRY.
3 UNDER SECTION 20 (7)	A DIRECTOR OF THE MINISTRY MAY REQUIRE THE OWNER OF A FLOWING WELL TO REGULATE THE FLOW OF WATER FROM THE WELL.
4 UNDER SECTION 22c, 22g	WATER-WELL CONTRACTORS AND TECHNICIANS OPERATING IN THE PROVINCE ARE REQUIRED TO OBTAIN AN APPROPRIATE LICENCE FROM THE DIRECTOR, WATER RESOURCES, OF THE MINISTRY TO CARRY ON THE BUSINESS OF CONSTRUCTING WATER WELLS AND TO WORK AT THE CONSTRUCTION OF WATER WELLS RESPECTIVELY.
5 UNDER REGULATION 612/84	THE CONSTRUCTION AND MAINTENANCE DETAILS OF WELLS ARE SET FORTH. SPECIALLY, CASING MATERIALS, SEALING AROUND THE CASING, CHLORINATION, CAPPING AND VENTING ARE COVERED. THE INSTALLATION OF PUMPING EQUIPMENT AND ITS RELATION TO VENTING AND PROPER SUB-SURFACE CONNECTIONS TO THE WELL CASING ARE ALSO COVERED. IN ADDITION, THE OWNER OF A WELL IS REQUIRED TO MAINTAIN IT AT ALL TIMES AFTER COMPLETION IN SUCH A MANNER AS TO PREVENT THE ENTRY OF SURFACE WATER OR FOREIGN MATERIALS. THE OWNER IS REQUIRED TO SEAL OFF SALTY, SULPHUROUS OR OTHER NON-POTABLE WATER ENCOUNTERED IN THE WELL IN A MANNER SUFFICIENT TO PREVENT IMPAIRMENT OF THE QUALITY OF GROUND WATER. THE CONTRACTOR IS REQUIRED TO PROVIDE A COPY OF THE WATER-WELL RECORD TO THE OWNER OF THE WELL.

FOR FURTHER INFORMATION ON WELL CONSTRUCTION AND MAINTENANCE DETAILS, REFERENCE SHOULD BE MADE TO THE APPROPRIATE SECTIONS OF THE ONTARIO WATER RESOURCES ACT AND REGULATION AVAILABLE FROM THE WATER RESOURCES BRANCH, MINISTRY OF THE ENVIRONMENT.

INSTRUCTIONS AND EXPLANATIONS

1 THE MINISTRY OF THE ENVIRONMENT COPY OF THE WATER-WELL RECORD FORM SHALL BE RETURNED TO THE WATER RESOURCES BRANCH, MINISTRY OF THE ENVIRONMENT, TORONTO, ONTARIO, WITHIN ONE MONTH AFTER THE COMPLETION OF THE WELL.
THE OWNER'S COPY OF THE WATER-WELL RECORD FORM SHALL BE SUBMITTED TO THE OWNER WITHIN TWO WEEKS AFTER THE COMPLETION.

2 WATER LEVEL MEASUREMENTS: DISTANCE BETWEEN THE SURFACE OF THE GROUND AND THE TOP OF THE WATER IN THE WELL.

3 WATER RECORD: DEPTH(S) AT WHICH WATER FOUND. THE DISTANCE FROM THE SURFACE OF THE GROUND TO THE WATER-BEARING FORMATION, OR HORIZON, WHERE WATER IS FOUND. THERE MAY BE MORE THAN ONE HORIZON.

4 LOG OF OVERBURDEN AND BEDROCK MATERIALS: FOR EACH FORMATION ENCOUNTERED IN DRILLING, CHOOSE WORDS FROM THE LISTS BELOW THAT BEST DESCRIBE THE FORMATION ON THE BASIS OF GENERAL COLOUR, MOST COMMON MATERIAL, OTHER MATERIALS AND GENERAL DESCRIPTION OF THE FORMATION. PLACE THESE WORDS IN THE CORRECT COLUMNS ON THE FRONT OF THE RECORD.

GENERAL COLOURS	M A T E R I A L S		GENERAL DESCRIPTIONS
WHITE	FILL	LIMESTONE	LOOSE
GREY	TOP SOIL	DOLOMITE	POROUS
BLUE	MUCK	SHALE	DENSE
GREEN	PEAT	SANDSTONE	PACKED
YELLOW	CLAY	SLATE	CEMENTED
BROWN	SILT	QUARTZITE	LAYERED
RED	FINE SAND	GRANITE	SOFT
BLACK	MEDIUM SAND	GREENSTONE	HARD
	COARSE SAND		WOOD FRAGMENTS
	GRAVEL		
	STONES		PREVIOUSLY DUG OR BORED
	BOULDERS		PREVIOUSLY DRILLED

EXAMPLE OF LOG

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET	
				FROM	TO
BROWN	TOP SOIL			0	2
GREY	SAND	GRAVEL, SILT	LOOSE, WOOD FRAGMENTS	2	41
BLUE	CLAY	SILT, STONES	DENSE	41	83
BROWN	FINE SAND	CLAY		83	102
GREY	LIMESTONE		POROUS, HARD	102	110

CLAY: COMPOSED OF VERY FINE PARTICLES. FORMS DENSE HARD LUMPS OR CLODS WHEN DRY AND A VERY ELASTIC PUTTY-LIKE MASS WHEN WET. IT CAN BE ROLLED BETWEEN FINGERS TO FORM A LONG, FLEXIBLE RIBBON.

SILT: GRAIN SIZE MIDWAY BETWEEN SAND AND CLAY. IT MAY FORM CLODS WHICH, WHEN BROKEN, FEEL SOFT AND FLOURY WHEN MOIST. IT WILL FORM A CAST THAT CAN BE HANDLED FREELY WITHOUT BREAKING. ROLLED BETWEEN THUMB AND FINGER, IT WILL NOT 'RIBBON' BUT WILL GIVE A BROKEN APPEARANCE.

SAND: GRAINS ARE LOOSE AND GRANULAR AND MAY BE SEEN AND FELT READILY. SQUEEZED IN THE HAND WHEN DRY, IT FALLS APART WHEN THE PRESSURE IS RELEASED. SQUEEZED WHEN MOIST, IT WILL FORM A CAST THAT WILL CRUMBLE WHEN TOUCHED. SHOULD BE LISTED AS FINE, MEDIUM OR COARSE.

GRAVEL: ROCK FRAGMENTS GREATER THAN ONE EIGHTH OF AN INCH IN DIAMETER.

5 LOCATION OF WELL: IT IS ESSENTIAL TO KNOW THE LOCATION OF EACH WELL AS ACCURATELY AS POSSIBLE. TWO DISTANCES ARE ALWAYS NECESSARY IN RURAL AREAS. ONE DISTANCE SHOULD BE TAKEN FROM A ROAD AND THE OTHER FROM EITHER A ROAD OR A TOWNSHIP LOT LINE (FIG. 1). IN A VILLAGE, TOWN OR CITY, BOTH DISTANCES SHOULD BE TAKEN FROM NAMED STREETS (FIG. 2). IN AREAS WHERE IT IS DIFFICULT TO OBTAIN LOT AND CONCESSION NUMBERS, SUFFICIENT INFORMATION SHOULD BE SUPPLIED IN THE DIAGRAM SO THAT THE WELL CAN BE RELATED TO A KNOWN UNIT SUCH AS A MAIN HIGHWAY, RAILWAY OR MUNICIPALITY (FIGS. 3 & 4).

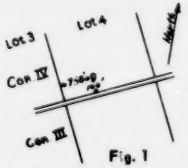


Fig. 1

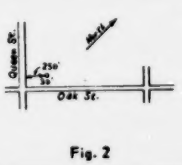


Fig. 2

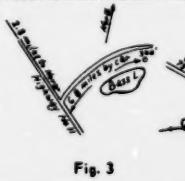


Fig. 3

Fig. 4

APPENDIX C
WELL CONTRACT SPECIFICATION GUIDELINE

Listed below are example items for consideration when drawing up a contract with your well contractor.

1. The Owner hereby retains the services of the Contractor for the purposes of constructing on the lands of the Owner a water well _____ millimetres in diameter.

2. The Contractor agrees to construct the well having a diameter as indicated in Clause 1, to supply and install the proper and necessary casing and to install and develop to an essentially sand-free state a well screen if required, for the prices referred to in Clause 4.

3. The Contractor agrees to endeavor to construct the said well to a sufficient depth to obtain the proper quality and quantity of water and to properly install no less than 6 metres of casing therein, unless the only useful aquifer requires less casing.

4. The Owner agrees to pay to the Contractor for the work referred to in this Agreement, $ _____ per metre for drilling/boring/digging, in rock/overburden, $ _____ per metre for casing and $ _____ per metre for well screen, which shall be paid as follows:

   (a) $ _____ on signing of this Agreement by the Contractor, and

   (b) the balance in a lump sum upon the work being completed to the satisfaction of the Owner.

5. At a depth of _____ metres, providing sufficient water has not been encountered above this said depth, permission from the owner to construct beyond the said depth shall be obtained and the contractor shall construct to a further depth to be agreed upon by the parties hereto (at a price and on terms to be agreed upon by the parties hereto).

6. It is hereby agreed that the depth in metres shall be determined by measuring from the land surface to the bottom of the constructed well in the presence of the owner or his representative and that the number of metres of casing and well screen shall be determined in accordance with the amount actually installed by the Contractor.

7. The Contractor shall ensure that the said water well is constructed, cased, tested and completed in compliance with Ontario Regulation 612/84.

8. The Contractor warrants and guarantees that the work to be performed under this Agreement shall be executed and completed in a proper and workmanlike manner, but does not warrant or guarantee that water will be obtained or that water, if obtained, will be of a sufficient or proper quality or quantity.

9. Upon completion of the work to be performed by the Contractor under this Agreement, the Contractor shall complete a Water Well Record prescribed by the Ministry of the Environment for the Province of Ontario and shall forward a copy of such record to the Water Resources Branch, Ministry of the Environment, and a copy to the Owner.

10. The Owner shall permit the Contractor, its officers, servants, employees and agents, free and unobstructed access to the site of the said water well for the purpose of carrying out the provisions of this Agreement.

APPENDIX D
LOCATION MAP AND ADDRESSES OF THE MINISTRY OF THE ENVIRONMENT OFFICES AND ADDRESSES OF THE MINISTRY OF HEALTH REGIONAL PUBLIC HEALTH LABORATORIES

MINISTRY OF THE ENVIRONMENT OFFICES

REGION 1 - SOUTHWESTERN

LONDON (519 661-2200)
985 Adelaide St. South
N6E 1V3

WINDSOR (519 254-2546)
250 Windsor Ave. W.
6th Floor
N9A 6V9

SARNIA (519 336-4030)
265 N. Front St.
N7T 7X1

OWEN SOUND (519 371-2901)
1180 20th St.
N4K 6H6

CHATHAM (519 354-2150)
P.O. BOX 726
435 Grand Ave. W.
N7M 5L1

CLINTON (519 482-3428)
c/o Ministry of Agric. & Food
P.O. Box 688
N0M 1L0

REGION 2 - WEST CENTRAL

HAMILTON (416 521-7640)
P.O. Box 2112
119 King St. W. 12th Floor
L8N 3Z9

CAMBRIDGE (519 653-1511)
P.O. Box 219
400 Clyde Road
N1R 5T8

WELLAND (416 384-9896)
637-641 Niagara St. North
L3C 1L9

REGION 3 - CENTRAL

TORONTO (416 424-3000)
7 Overlea Blvd.
M4H 1A8

OAKVILLE (416 844-5747)
1235 Trafalgar Rd., Suite 401
L6H 3P1

BARRIE (705 726-1730)
12 Fairview Rd.
L4N 4P3

GRAVENHURST (705 687-3408)
Gravenhurst Plaza
General Delivery
P0C 1G0

PETERBOROUGH (705 743-2972)
139 George St. N.
K9J 3G6

REGION 4 - SOUTHEASTERN

KINGSTON (613 549-4000)
P.O. Box 820
133 Dalton Ave.
K7L 4X6

CORNWALL (613 933-7402)
205 Amelia Road
K6H 3P3

BELLEVILLE (613 962-9208)
15 Victoria Avenue
K8N 1Z5

OTTAWA (613 521-3450)
2378 Holly Lane
K1V 7P1

PEMBROKE (613 732-3643)
1000 MacKay St.
K8B 1A3

REGION 5 - NORTHEASTERN

SUDBURY (705 675-4501)
199 Larch St., 11th Floor
P3E 5P9

NORTH BAY (705 476-1001)
1500 Fisher Street
Northgate Plaza
P1B 2H3

SAULT STE. MARIE (705 949-4640)
445 Albert St. East
P6A 2J9

PARRY SOUND (705 746-2139)
74 Church Street
P2A 1Z1

TIMMINS (705 264-9474)
83 Algonquin Blvd. W.
P4N 2R4

REGION 6 - NORTHWESTERN

THUNDER BAY (807 475-1205)
P.O. Box 5000
435 James St. S., 3rd Floor
P7C 5G6

KENORA (807 468-5578)
P.O. Box 5150
808 Robertson St.
P9N 1X9

WATER RESOURCES BRANCH

(416 323-4868)
135 St. Clair Avenue West, 3rd Floor
Toronto, Ontario
M4V 1P5

ONTARIO MINISTRY OF HEALTH
REGIONAL PUBLIC HEALTH LABORATORIES

LONDON (519 455-9310)
London Psychiatric Hospital
Highbury Avenue
P.O. Box 5704, Terminal A
N6A 4L6

SARNIA (519 344-3661)
Sarnia General Hospital
220 North Mitton Street
N7T 6H6

WINDSOR (519 969-4341)
3400 Huron Church Road
P.O. Box 1616
N9A 6S2

PALMERSTON (519 343-3102)
Midwestern Reg. Children's
Centre Highway 23
P.O. Box 700
N0G 2P0

HAMILTON (416 385-5379)
Hamilton Psychiatric Hospital
Fennell Avenue West
L8N 3R5

PETERBOROUGH (705 743-6811)
1341 Dobbin Avenue
P.O. Box 265
K9J 6Y8

ORILLIA (705 325-7449)
Highway 11B
P.O. Box 600
L3V 6K5

KINGSTON (613 547-2292)
181 Barrie Street
P.O. Box 240
K7L 4V8
K2A 1S8

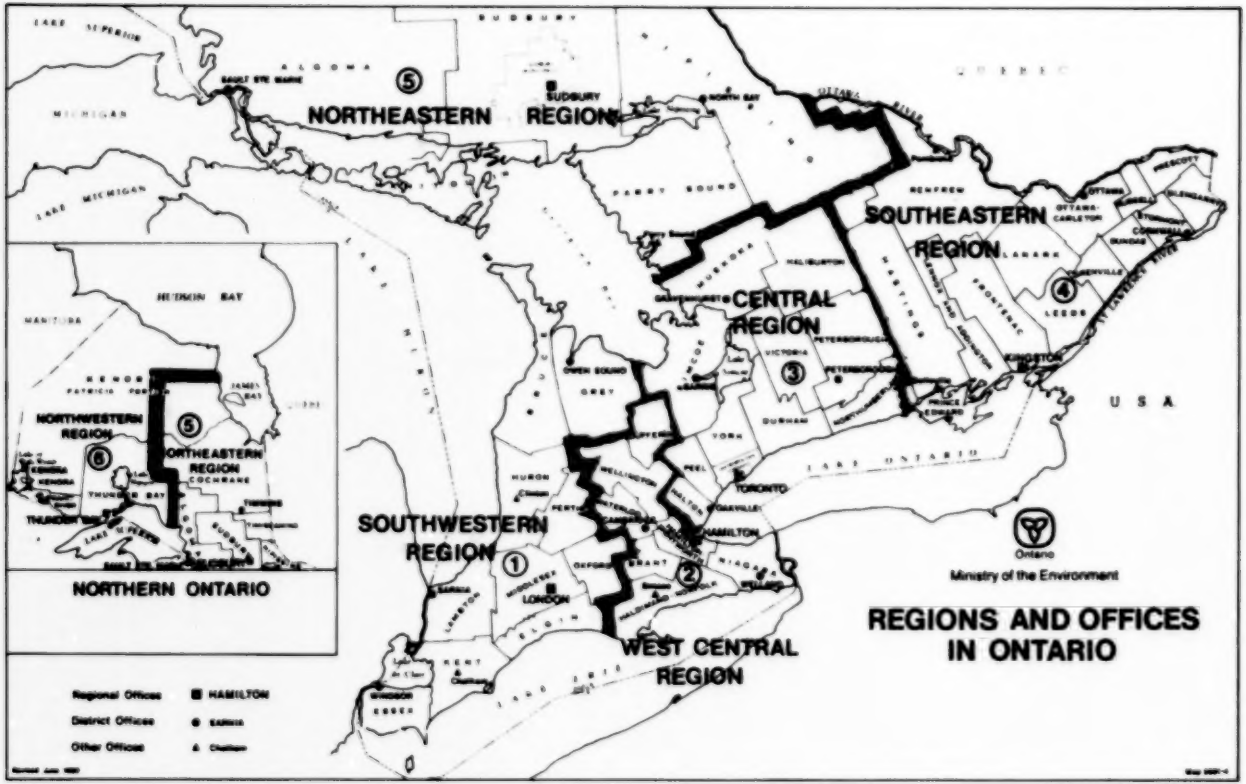
OTTAWA (613 828-2442)
346 Moodie Drive
R.R.#2 Bell's Corners
P.O. Box 6301, Station "J"

SUDBURY (705 522-2640)
1300 Paris Crescent
P3E 3A3

TIMMINS (705 264-9571)
67 Wilson Avenue
P4N 2S5

SAULT STE. MARIE (705 254-7132)
Albert and Block Streets
P.O. Box 220
P6A 5L6

THUNDER BAY (807 622-6449)
336 S. Syndicate Ave.
P.O. Box 1100, Station "F"
P7C 4X9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SUDBURY
REGIONS
SOUTHEASTERN REGION
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CENTRAL REGION
3
SOUTHWESTERN REGION
1
WEST CENTRAL REGION
2
NORTHWESTERN REGION
6
NORTHEASTERN REGION
COCHRANE
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LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
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HUDSON BAY
MANITOBA
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QUEBEC
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SUDBURY
ALGOMA
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OXFORD
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NIAGARA
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REGIONS AND OFFICES IN ONTARIO

APPENDIX E
CHLORINATION PROCEDURE FOR DOMESTIC WELLS

Ontario Regulation 612/84 requires that all newly constructed wells be chlorinated by the well contractor *with 250 milligrams per litre* available chlorine over a contact time of 12 hours.

The chlorination of existing wells because of a poor bacteriological analysis results or following repairs to either the well or the pump requires *only 50 milligrams per litre* over a contact time of 12 hours.

The following are two examples of procedures recommended to calculate the amount of bleach required to chlorinate a well.

1. A simple formula (Environmental Health Review, Spring 1986) for directly calculating in either the Imperial or Metric systems the amount of household bleach (5.25% sodium hypochlorite) to add to your well water to obtain *250 mg/L* available chlorine is given below:

   $15\ R^2H = Q$ — where: R is the radius of the well in feet or metres, H is the number of feet or metres of water in the well casing, Q is the number of litres or fluid ounces that must be added to the well water.

2. Measure the diameter of well.

   Determine by measurement the number of metres of water in the well.

   From the following table obtain the volume of water in litres contained in the well for every metre of water.

Inside Diameter (millimetres)	Litres per Metre Water in the Well
50.8	2.03
101.6	8.11
127.0	12.7
152.4	18.2
177.8	24.8
203.2	32.4
609.6	291.9
762.0	456.0
914.4	656.7

After calculating the number of litres of water in the well, calculate the amount of chlorine or compound containing chlorine that must be added to the well water to obtain the desirable concentration. Numerous household bleach solutions (Javex) containing sodium hypochlorite are available and they contain about 3 to 5.25 percent available chlorine. Calcium hypochlorite is also available in granular or tablet form and contain about 70% available chlorine by weight. Either of these two products may be used. The following relationship will help you to determine the amount of these products to add to your well water. For every 1,000 litres of well water add: 1 litre of household bleach (5%) or 71 grams of calcium hypochlorite to obtain a 50 mg/L concentration of chlorine and 5 litres of household bleach or 355 grams of calcium hypochlorite to obtain a 250 mg/L concentration of chlorine.

Thoroughly mix the chlorine solution or powder with the water in the well. The objective is to add sufficient chlorine (solution, powder or tablets) to the well water so that the mixture of chlorine to well water *throughout* the cased and screened portions of the well will yield the required chlorine concentration. The chlorine should be placed at the bottom of the well either by dropping tablets into the well and allowing them to settle or be adding a chlorine solution through a "tremie" pipe. The mixing is accomplished by surging (pump) or bailing. Some agitation is necessary to ensure adequate contact throughout all parts of the well.

Another method is to place the required quantity of chlorine powder or tablets into a weighted porous container. This container is then surged up and down in the well until the contents are dissolved.

Before disinfecting the water distribution system, remove or isolate any carbon filter from the system since a filter will tend to remove the chlorine. In addition, the water heater should be completely drained and allowed to fill with chlorinated water.

Open all the taps in the pressure system until you can smell chlorine and then turn the taps off. This will thoroughly chlorinate the plumbing fixtures.

Allow the solution to remain in the water system for at least 12 hours.

After the 12 hours discharge the water in the system to waste until the smell of chlorine disappears. None of the water being wasted should be

allowed to enter the septic tank and tile field. The amount of chlorine remaining in the water will not be harmful.

In about a week send a water sample to the local Health Unit for a bacteriological examination. Boil or chlorinate all drinking water until the bacteriological results are returned. Two consecutive "safe" tests will probably indicate that the treatment has been effective.

If tests show continuing bacteriological contamination, a second chlorination is needed. Following the second treatment additional tests should be conducted. After repeated positive bacteriological tests, a well contractor should be contacted to surge the well and the surrounding formation with a strong chlorine solution.

Chlorination will sterilize a well and water system; however, unless the source of the bacterial contamination is found and corrected the problem will continue to reoccur and chlorination will not solve the problem. Some of the precautions that can be taken to eliminate sources of bacterial contamination of wells are given on Page 72. In some cases, a new well may have to be constructed to correct the problem.

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